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Plutonium Burdens in People Living Around the Rocky Flats Plant

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PLUTONIUM BURDENS IN PEOPLE LIVING AROUND THE ROCKY FLATS PLANT

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16. ABSTRACT

A study was conducted to determine whether the tissues of people who lived near to or downwind from the Rocky Flats nuclear weapons facility in Colorado contained more plutonium than the tissues from people who lived farther away. Information was collected on the age, sex, smoking history, residence history, presence of disease, and plutonium level in selected tissues from individuals autopsied in various Eastern Colorado hospitals. The 236, 238, 239 and 240 isotopes of plutonium were determined.

Plutonium levels in lung and liver tissues were affected by age and smoking history more than by distance from the Rocky Flats Plant. Though the measured 240/239 isotope ratio indicated a small contribution from Rocky Flats, the total amount of plutonium in the samples was no different than in similar samples collected from other areas of the U. S.

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PREFACE

The biosphere in which we live, and depend on for life, must be protected from the adverse effects of our pollution. The Division of Community Health at the University of Colorado Health Sciences Center is concerned with epidemiological studies to evaluate the extent of environmental pollution and its effects on human health. This requires a multidisciplinary focus on the various aspects of our physical environment including air, water, land and radiation in relation to the biosphere.

The report that follows is concerned with measurement of the amount of plutonium coming from our nuclear weapons industry which has found its way into human tissues. This is important because of the mutagenic and carcinogenic effects of the alpha radiations which are given off into these tissues by this radioactive element.

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ABSTRACT

This research program was initiated with the objective of finding out whether plutonium from the Rocky Flats Nuclear Weapons Facility near Denver was getting into the tissues of people who resided nearby. This report describes the methods of collecting the 519 sets of autopsy tissues from hospitals in eastern Colorado, the epidemiologic data collection, the methods of determination of plutonium activity levels by alpha pulse height analysis and mass spectrometry, and of determining the ratio of the isotopes, plutonium 240/plutonium 239. The quality assurance data and findings are reported. A statistical analysis of the data is presented regarding the relationship of plutonium lung and liver burdens and Pu 240/239 isotope ratios in lungs and livers to various independent variables: age, sex, smoking history, pathological conditions, and residence near the Rocky Flats Nuclear Weapons Facility. Results of multiple regression analyses suggest that plutonium burden is evidently related to age, sex, and smoking history and possibly, at most, weakly related to residence near Rocky Flats.

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SECTION 1

INTRODUCTION

The study, initiated in 1975, was the result of a request from Senator Haskell (U.S. Senator of Colorado) to the EPA Administrator, Russell Train, for a study to determine the presence, extent, and potential effects of plutonium in people living in areas surrounding the Rocky Flats Nuclear Weapons Facility. The study, as directed by Mr. Train, was designed to compare the levels of plutonium in human autopsy tissues in those who lived near Rocky Flats with those who had lived in Denver and Pueblo, Colorado, and hopefully to determine the source of any plutonium found.

The Environmental Protection Agency (EPA) Environmental Monitoring Systems Laboratory, Las Vegas, Nevada (EMSL-LV) designed the study in consultation with staff from the University of Colorado Medical Center (UCMC)(1), and the Colorado State Health Department. The original design called for collection of tissue specimens from human autopsies in each of three collection areas, i.e., Area A= the area up to 25 km from the Rocky Flats Facility, Area B = between 25-50 km from the Rocky Flats Facility, and Area C = the vicinity of Pueblo, Colorado. The Control Area was later expanded to include all of Colorado outside the 50 km radius circle and east of the Continental Divide. The goal was to get enough sets of autopsy tissues from each of the three areas, so that we could measure a difference in plutonium organ burden at the level that would be expected from the available data on plutonium in air and soil samples. We were

(1) The name has now been changed to University of Colorado Health Sciences Center.

aiming at the goal of 173 autopsies from each area, for a total of 519. Our findings could be compared with the approximately 200 sets of liver and lung plutonium (Pu) measurements in Colorado residents, reported by McInroy (1979), and the 36 liver and 20 lung measurements in accident victims in New York City reported by Fisenne (1979).

This study differs from these previously reported studies (McInroy, 1979 and Fisenne, 1979) in two important ways: 1) this study devotes significantly more effort to documenting residence history, smoking history, and occupational exposure of the individuals whose tissues were collected, and 2) because of the analytical difficulties encountered in the measurements of plutonium in human tissues, this study has a rigorous quality assurance (Q.A.) program to document the validity of the plutonium analyses.

In addition to getting data on the tissue concentrations of plutonium in different individuals, we have some sets of measurements on paired samples from the same individuals which give information on the homogeneity of plutonium distribution in lung and liver; and rather than estimating burdens for standard organ weight, we used actual organ weights to compute the actual total lung burden and total liver burden. This study also reports the ratios of the plutonium isotopes 240/239, as measured by mass spectrometry. This provides information about the source of the plutonium found in these human tissues.

The usefulness of these data is not limited to the above questions about Rocky Flats; for example the smoking history and the pathological data would permit investigation of the influence of smoking and of various pathological conditions on plutonium concentration and on total plutonium burden in lung and liver.

SECTION 2

METHODS AND PROCEDURES

METHODOLOGY

In June 1975, the Environmental Protection Agency (EPA) awarded a contract to the University of Colorado Medical Center (UCMC) to collect tissue samples in each of the three collection areas and to get the epidemiological data. Because of the slow collection rate in Pueblo, we expanded the Control Area in 1977 to include all of Colorado east of the Continental Divide that is more than 50 km from the Rocky Flats Weapons Facility. Each set of samples collected usually included: (1) one whole lung (right or left); (2) approximately 750 grams of liver; (3) both gonads, if available; (4) both adrenals, if available; and (5) a sample of rib. The U.S. Air Force's McClellan Central Laboratory (MCL) in Sacramento, California, analyzed lung and liver samples by both alpha pulse height analysis (APHA) and mass spectrometry (MS) in accordance with an Interagency Agreement between the EPA and the U.S. Air Force. (The gonad, rib, and adrenal samples have not yet been analyzed for plutonium.) Both the APHA analyses and the MS analyses served to determine quantities of plutonium; the MS analyses also provided the ratio of Plutonium 240 to Plutonium 239 for each sample.

The EPA made the decision regarding which tissues, and how many would be collected, on the basis of what was then known about plutonium distribution in the body resulting from inhaled $Pu\ O_4$ particles. We were cognizant of the fact that pulmonary lymph nodes in the lung parenchyma and along the tracheobronchial tree tend to concentrate plutonium particles from the lungs. This led to the decision to include these pulmonary lymph nodes with the lung specimens. We recognized that, under the conditions of this study, it would not be possible to dissect them all out, especially those deep in the lung parenchyma. Thus, to separate out some of them would have caused an arbitrary bias.

The presumption was that plutonium would have been carried by the blood stream from the lungs to the other organs and would have been deposited more permanently and more evenly there. Thus we expected that the plutonium concentrations in the liver would be higher and more homogeneous than in the lung. Liver and lung specimens were run first because of the greater difficulties and greater variability involved with bone determinations and because the gonad and adrenal specimens were too small to give measurable results for individual cases. We hoped to get measurements of plutonium levels on pooled samples of gonads and adrenals.

Sample size projections were made, based on the small amount of preliminary data. It was estimated that samples of between 70 and 130 in each group (proximal and distal) should be able to detect a relative risk of about 1.5, if such a risk existed, with over 90% power.

Based on the autopsy rates at the time the study was designed, we anticipated that sample collection would be completed in June 1977. However, because the Joint Committee on Hospital Accreditation dropped the requirement for autopsies, autopsy collection rates in the three collection areas decreased by about 70%. Therefore, the collection period had to be extended two additional years.

COLLECTION OF TISSUE

Fifteen hospitals in Denver, Pueblo, and Colorado Springs agreed to collect tissue samples for the Study. Names of the fifteen hospitals are shown in Appendix A.

The collection of tissue required several steps. First, for all eligible decedents coming to autopsy, the hospital staff were asked to obtain an informed consent from the next of kin specifically for this study in addition to the usual hospital consent forms. (At Penrose Hospital, the existing consent form covered the purpose of the study.) One section of the informed consent provided preliminary information to screen out individuals who might have been occupationally exposed to plutonium or who did not live in one of the study areas. To be eligible, a decedent must have lived in one of the study areas and must not have worked at a plutonium processing facility or at any place where he might have been occupationally exposed to plutonium. A typical informed consent is shown in Appendix B. This portion of the Study depended upon the cooperation of several hundred individuals (staff doctors, resident doctors, nursing staff, pathology staff, and administrative staff) in the participating hospitals.

The above described method of collecting tissues tended to have a bias toward collection of "interesting cases" from the point of view of the clinicians and pathologists, and there may have been a bias introduced favoring collection of tissues from cases where somebody, perhaps the physician or the family, thought that the patient's disease might have been related to plutonium exposure, especially if the patient had lived near Rocky Flats. These data would thus be ill-suited for, and were not intended for, any study of the possibility that the plutonium burden may have been an underlying cause of any pathological conditions.

The second step involved the actual collection of the sets of tissue specimens and associated information. The pathology staff of each cooperating hospital recorded information about the decedent according to an established protocol. (The protocols and data on tissues collected are shown in Appendix C.) The pathology staff then placed the sets of tissue specimens in polyethylene bags, labeled as to type of tissue and autopsy number. Periodically, the UCMC staff picked up the sets of tissue specimens from the individual hospitals and brought them to UCMC where they assigned a number to each tissue sample, weighed it, logged it, and froze it. The information logged by UCMC staff included identifying information about the decedent and any deviations from the collection protocol such as "gonads not submitted." An example of the logbook entry is shown in Appendix D. In hospitals located outside the Denver Metropolitan area, the pathology staff froze the samples and stored them in freezers provided by the Study contract at each such hospital.

The UCMC staff labeled the samples according to the system below. XXX represents the UCMC case numbers, assigned consecutively, for each individual in the study (001 through 519).

2XXX - Liver sample
3XXX - Lung sample
4XXX - Rib sample
5XXX - Gonad sample
6XXX - Adrenal sample
7XXX - Liver sample
8XXX - Lung sample
9XXX - Additional sample

There were 74 cases collected by the end of the first year (30 June 1976); by the end of the second year, 116 additional cases were added bringing the case number to 190; in the third year, another 163 were added for a total of 353, and by 30 June 1979, another 164 cases brought the total to 517. Only two cases were added after that date.

In order to simplify the presentation in the tables that follow, the UCMC case numbers are printed first, using a suffix number, rather than a prefix, to indicate the type of tissue. Thus, 519-2 would be a liver sample from the last case in our study, and 519-7 would be a second liver sample from the same individual.

Because the gonads of many women and some men had been surgically removed prior to death, gonadal tissue samples were not always available. Occasionally, the pathologist kept some of the tissue (lung, liver, etc.) for other purposes so that it was not available for this study. The pathologist recorded the weight of the lungs and liver at the time of autopsy, and indicated what percentage of the total gonadal and adrenal tissue was provided to the study. Due to funding limitations, out of the original population of 519 autopsies obtained for the purposes of this study, the lung and liver tissues from 46 individuals (and the bone, gonad, and adrenal tissues from all cases) have not yet been analysed for plutonium. Of the remaining 473 individuals (the "Pu analysed" population) whose lungs and/or livers were analysed for plutonium, there are 5 for whom we were unable to get the necessary epidemiological data from interviews with next of kin. For the 468 for whom interviews were obtained, an additional 19 were ruled out either because they had been (or might have been) occupationally exposed to plutonium, or because they had lived (or might have lived) in plutonium contaminated areas other than metropolitan Denver, (e.g. downwind near the Nevada Test Site). This leaves a total of 449 individuals which we shall call "The Study Population." So far as we could tell, none of these were exposed to plutonium from sources other than fallout and/or environmental contamination from the Rocky Flats Plant.

COLLECTION OF EPIDEMIOLOGIC DATA

The third step consisted of a standardized telephone interview (Appendix E) with the next of kin. In general, before telephoning, the UCMC staff obtained permission from the attending physician. The purpose of the interview was to obtain a detailed history of the various places of residence of the decedent, to discover possible occupational plutonium exposure and possible plutonium exposure in places like the South Pacific atom bomb test areas or Utah, Nevada and the Western Slope of Colorado where they might have gotten plutonium from the Nevada Test Site activities. A history of smoking was also obtained. The form shown in Appendix F is an example of the form used to record this telephone interview information. From the beginning of the study until July 1977 the UCMC staff obtained detailed residence histories from 1968 to death but also querried them to rule out any possible plutonium exposure in places like the South Pacific or Nevada Test Site, at any time in their life. Beginning in July 1977, they asked for detailed residence histories from 1956 to death.

Residence history is presented in Table 1, pathological data in Table 2, and Table 3 shows the smoking history and possible exposure to weapons grade plutonium from other sources. Figure 1 shows the breakdown of our Autopsy Population of 519 individuals according to the various categories. Utilizing the residence of each individual at the time of death, the total population of 519 individuals are distributed as follows: there are 147 tissue sets from Area A (<25 km), 182 from Area B (25-50 km), and 190 from the Control Area (>50 km). Some of these people had lived in more than one of these areas, and some of these tissues were not utilized in the study, as described above. (See Section 4 for a detailed statistical analysis of residence histories, etc.)

SHIPMENT OF TISSUES

Prior to shipping the tissues to MCL, the UCMC staff weighed the tissue a second time and compared this weight with the original weight recorded in the logbook. Conformity in these weights served as a double check on the proper identification of each tissue sample and served as a check on the accuracy of the first weighing. Since MCL did not have access to residence information, they had no way of knowing which tissue came from which area. In addition, the UCMC staff shipped sporadically interspersed Quality Assurance (Q.A.) samples with non-Q.A. samples so that the MCL staff could not identify the Q.A. samples.

The UCMC staff packed the tissues in dry ice and shipped them by airfreight to MCL. A shipment usually consisted of 10 lung and 10 liver samples, and would typically include 1 or 2 Q.A. samples.

The MCL staff also weighed each tissue sample at the time of the laboratory analysis, (see step 4.1.2 of Appendix H). These weights were generally about 20 grams less than the weights recorded by the UCMC staff because of the weights of the plastic bags and the small amount of frozen liquid discarded with the bags. In 3 samples, (sample numbers, 139-3, 354-2, and 371-2) the MCL weight differed by more than 100 grams from the UCMC weight probably due to transcribing error at MCL. In these cases, the second UCMC weight is the one shown in Table 5. Otherwise, the weights shown in Table 5 are the MCL weights.

Figure 1 shows the breakdown of the 519 sets of autopsy tissues collected for this study. Note that Table 5 includes all the data on Pu 239+240 analyses reported by MCL on the 473 individuals. Some of these were not included in the "Study Population" which we used for the multiple regression analyses, because they had possibly been exposed to weapons grade plutonium as a result of residing in Utah, Nevada or the Western Slope of Colorado, might have been occupationally exposed, or because their tissues were spiked with Pu 239 as part of the quality assurance program.

Toward the end of the study, limitation of funds precluded getting plutonium analyses on the last 41 "Extra C" cases from the control area; but these were not essential for the purposes of the study.

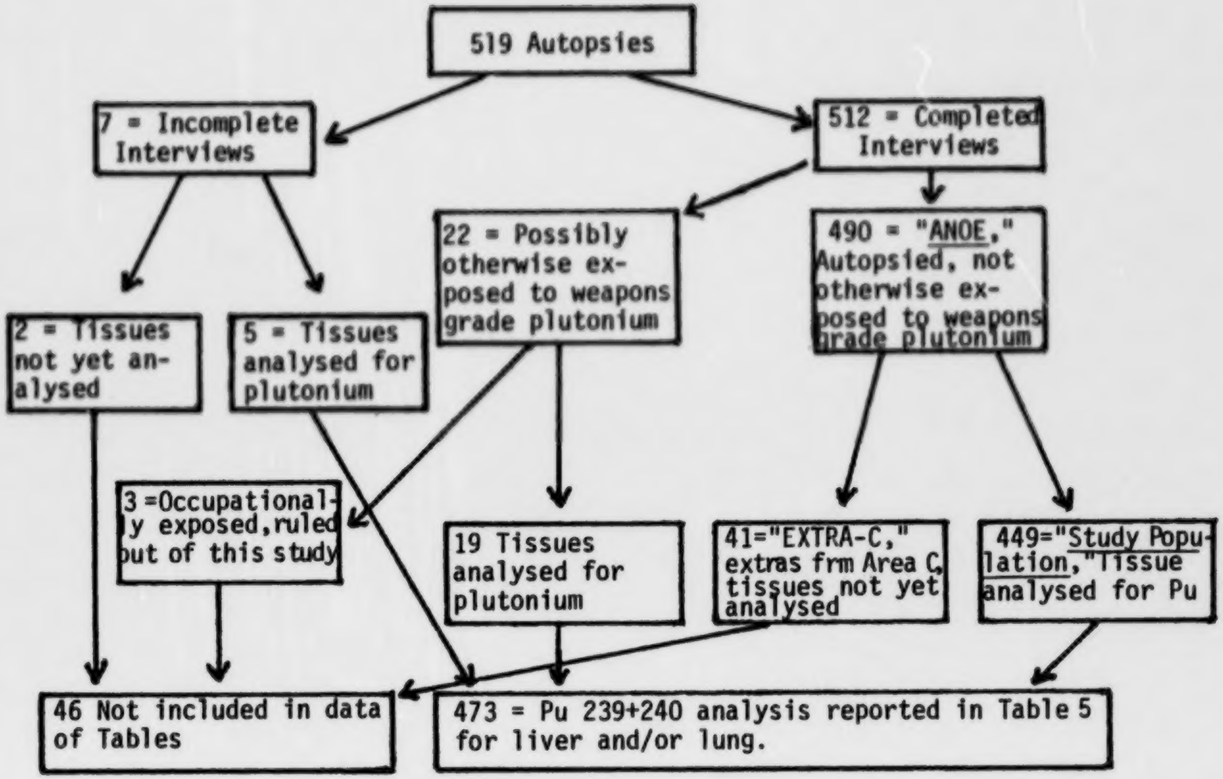

519 Autopsies
7 = Incomplete Interviews
512 = Completed Interviews
2 = Tissues not yet analysed
5 = Tissues analysed for plutonium
22 = Possibly otherwise exposed to weapons grade plutonium
490 = "ANOE," Autopsied, not otherwise exposed to weapons grade plutonium
3 = Occupationally exposed, ruled out of this study
19 Tissues analysed for plutonium
41="EXTRA-C," extras frm Area C, tissues not yet analysed
449="Study Population," Tissue analysed for Pu
46 Not included in data of Tables
473 = Pu 239+240 analysis reported in Table 5 for liver and/or lung.

Figure 1. Breakdown of 519 Autopsied Individuals

TABLE 1

RESIDENCE HISTORY

CASE

Consecutive number assigned to a decedent's set of tissue samples.

RESIDENCE LOCATION

Coordinates are in tenths of a kilometer according to the Universal Transverse Mercator System.* The location of the approximate center of the Rocky Flats Nuclear Weapons Facility in this system is North Coordinate 44154 and East Coordinate 04826.

Columns 4,7,10, and 13 are the periods of residence in years, omitting the first two digits of the year. Thus 70-76 means 1970 to 1976. When, for very old people, the beginning date of a residence period was before the turn of the century, these dates are shown in the same way; thus 89-50 means 1889-1950. When the date is unknown, a blank is shown.

MOST RECENT RESIDENCE

Location of decedent's residence at the time of death and for the previous period shown in years, (e.g. 55-75 means that the decedent lived at that location from 1955 to the time of death in 1975).

NEXT MOST RECENT

The locations of earlier residences, when known, are shown in the same way with the period shown in years.

(Continued)

TABLE 1 (Continued)

INTERVIEW NOT OBTAINABLE

When the interview did not disclose the data on residence history with sufficient accuracy.

---

* The Universal Transverse Mercator System, used in mapping, considers the curved surface of the earth projected on a set of flat planes. The plane used in mapping Colorado has, for its western border, a north-south line in eastern Utah 482.6 km west of Rocky Flats. For the purpose of this study, points to the west of this line are shown with a negative sign for the East Coordinate, and the number is the approximate distance west of that line in tenths of a kilometer. Points south of the equator are similarly shown with a negative sign in the North Coordinate, and the number is the approximate distance in tenths of a kilometer south of the equator.

TABLE I

CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
1	44042	4967	55-75									
2	44045	4860	70-75	44044	4859	68-70						
3	44001	4940	74-75	43992	4908	69-74	43996	4907	68-69	45410	8290	-68
4	43962	4865	73-75	43872	4760	68-73						
5	44112	4962	68-75									
6	43972	4969	68-75									
7	43996	4813	68-75									
8	44089	4994	42-75									
9	44186	4932	66-75									
10	43964	5001	72-75	43998	4977	68-72						
11	43996	4945	66-75									
12	44168	5016	74-75	44192	4929	62-74						
13	44047	4926	68-75									
14	43933	4976	74-75	44013	4960	44-74						
15	43893	4966	59-75									
16	44007	4936	73-75	44007	4950	10-73						
17	44168	4926	62-75									
18	43967	4930	53-75									
19	44058	4915	70-75	43960	5131	68-70						
20	44019	4926	72-75	44020	4950	68-72						
21	44011	4892	46-76									
22	42350	5345	72-76	42350	5345	68-72						
23	42350	5345	72-76	42350	5345	70-72	42350	5345	68-70			
24	INTERVIEW NOT OBTAINABLE											
25	42350	5345	68-76									
26	43850	4150	37-75									
27	44175	4945	72-76	72810	-11720	59-72						
28	44019	4964	64-76									
29	43979	4835	68-76									
30	43989	4922	51-76									
31	44001	4896	50-76									
32	44014	4995	48-76									
33	43937	4986	55-76									
34	44014	4811	56-76									
35	44038	4967	52-76									
36	43973	4834	75-76	44006	4811	67-75						
37	44016	4954	70-76	44025	4931	20-70						
38	44030	4980	56-76									
39	42350	5345	68-76									
40	44040	4922	50-76									

TABLE I

CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
41	44017	4936	61-76									
42	44010	4970	51-76									
43	43921	4915	72-76	43000	5162	68-72						
44	43936	4958	64-76									
45	45350	4710	73-76	44300	4750	9-73						
46	43944	5050	70-76	43958	5019	50-70						
47	43912	5051	72-76	43958	5051	70-72	-24790	-53025	67-70			
48	44010	5065	68-76									
49	44016	5050	56-76									
50	43989	5069	36-76									
51	43983	5037	72-76	43983	5038	63-72	41300	2450	20-63			
52	44001	4898	66-76									
53	44041	5011	68-76									
54	44050	4930	75-76	44000	4817	50-75						
55	42350	5345	68-76									
56	43954	4971	49-76									
57	43979	4850	60-76									
58	43872	4760	62-76									
59	43929	5018	68-76									
60	43920	5058	70-76	43927	5015	55-70						
61	44088	4988	66-76	44015	4960	-66						
62	43975	4970	75-76	44084	4975	56-75						
63	43945	4993	68-76									
64	43954	4986	68-76									
65	43963	5018	72-76	43968	5058	68-72						
66	43938	4993	72-76	43920	4979	60-72						
67	43994	5030	71-76	43979	5023	61-71						
68	42350	5345	68-76									
69	44072	5068	68-76									
70	44617	4935	68-76									
71	43984	5047	75-76	43976	5013	74-75	43971	5026	68-74			
72	43929	5036	56-76									
73	44049	4916	71-76	47660	24740	12-71						
74	44013	4985	73-76	41130	5440	11-73						
75	43977	5077	68-76									
76	43951	4993	50-76									
77	44009	4944	67-76									
78	43953	4950	71-76	43990	4981	52-71						
79	44092	5083	64-76									
80	43971	4831	72-76	43999	4946	68-72						

TABLE I

CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
81	44028	4935	75-76				47720	18150	8-71			
82	44025	4927	72-76	43983	4872	70-72	44034	5039	45-70			
83	44019	4943	66-76									
84	43871	5102	68-76									
85	43918	5040	68-76									
86	43920	5029	68-76									
87	43909	5019	40-76									
88	42320	5567	68-76									
89	42350	5345	45-76									
90	43902	5075	76-76	43815	5007	62-76	43916	5029	45-62			
91	43818	5027	52-76									
92	43970	5116	59-76									
93	44018	4914	55-76									
94	44012	4802	75-76	44008	4806	68-75						
95	44015	5035	68-76									
96	43939	4944	68-76									
97	43923	4978	73-76	44124	5003	71-73	43893	4890	70-71	44072	4934	68-70
98	44019	4969	42-76									
99	43923	5058	68-76									
100	43999	5014	68-76									
101	43982	5146	68-76									
102	42350	5345	53-76									
103	42140	6560	67-76	42120	6120	63-67	42040	6280	60-63	42120	6120	57-60
104	42350	5345	58-76									
105	44030	4997	46-76									
106	44084	4898	68-76									
107	43984	5106	61-76	99000	-20000	55-61						
108	44025	4994	47-76									
109	44124	4992	70-76	44290	4759	56-70						
110	43975	4924	68-76									
111	43996	4819	49-76									
112	43979	4971	66-76	43955	4979	51-66						
113	42350	5340	52-76									
114	42200	5855	53-76									
115	44104	4950	60-76									
116	44006	4981	75-76	43942	5017	73-75	43917	5013	68-73			
117	43980	5021	68-76	43993	5015	-68						
118	43872	4760	68-76									
119	43905	5012	54-76									
120	42350	5345	10-76									

TABLE I

CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
121	42350	5345	68-76									
122	42350	5345	68-76									
123	43946	5106	68-76	44010	4940	-68						
124	44016	4952	58-76	46700	19320	-58						
125	43976	5027	68-76									
126	42350	5345	35-76									
127	41130	5440	56-76	42770	1030	51-53						
128	42350	5340	52-76									
129	42350	5340	63-76									
130	43996	5020	69-77									
131	43918	4901	74-77	38190	-7950	68-74						
132	43989	5015	68-77									
133	43888	4971	76-77	43400	3425	70-76	43280	1980	51-70			
134	43892	5025	75-77	43975	5068	72-75	43911	5070	68-72			
135	43923	4953	68-77									
136	44019	4945	68-77									
137	44004	4968	71-77	40880	13820	70-71	38360	-7590	68-70	44285	4772	63-68
138	42180	5990	61-77	42350	5340	9-61						
139	42040	6280	56-77									
140	42140	6560	64-77									
141	44097	4968	70-77	43672	5007	37-70						
142	44016	4966	68-77									
143	44026	4967	68-77									
144	44012	4966	70-77	43973	5045	60-70						
145	43885	4950	68-77									
146	43919	5065	59-77	43941	5016	56-58						
147	43950	4879	73-77	43998	4964	63-73	44061	4897	61-63			
148	44000	4550	68-77									
149	42350	5340	68-77									
150	43992	5031	76-77	43956	4997	68-76						
151	43990	5059	69-77	44150	-10370	68-69						
152	43994	5013	68-77									
153	44172	5031	65-77									
154	43953	4945	45-77									
155	43962	5006	69-77	43948	4988	57-69						
156	43950	5016	68-77									
157	44000	5020	68-77									
158	43919	4929	63-77	43930	4953	58-63	43928	4951	56-58			
159	44045	4924	58-77									
160	43925	4958	61-77	43110	1980	60-61	36700	4830	47-60			

TABLE I

CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
161	44003	4811	35-77									
162	44072	4972	71-77	44090	4967	70-71	43979	5013	59-70	43944	5014	57-59
163	43999	4821	68-77	43997	4875	64-68	43996	4815	56-64			
164	44102	4852	68-77									
165	44150	12000	73-77	44050	4919	68-73	44050	4919	-68			
166	44069	4973	74-77	44020	4947	71-74	43550	5460	68-71			
167	43978	4979	68-77	43973	4968	15-68						
168	44028	4956	68-77									
169	44032	4933	68-77									
170	42350	5340	34-77									
171	44835	3450	71-77	44765	4002	67-71	43968	5067	33-67			
172	42350	5340	48-77									
173	43986	4998	56-77									
174	43945	5030	42-77									
175	INTERVIEW NOT OBTAINABLE											
176	43948	4959	68-77									
177	43985	5022	56-77									
178	42180	7100	74-77	36790	4830	70-74	44070	5070	70-70	44440	6940	68-70
179	43981	5057	56-77									
180	44076	4921	60-77									
181	44090	5003	68-77									
182	43921	5016	68-77	43966	5034	46-68						
183	43979	5013	50-77									
184	44002	4980	68-77									
185	43998	5070	50-77									
186	42350	5340	56-77									
187	43979	5013	74-77	43988	5023	45-74						
188	43894	4966	56-77									
189	42350	5340	72-77	42350	5340	56-72						
190	44020	4978	68-77									
191	43988	5063	68-77									
192	43978	5022	76-77	43994	5016	73-76	44003	5016	69-73	51320	8970	39-69
193	43951	4967	68-77									
194	42350	5340	68-77	42350	5340	45-68						
195	41130	5430	65-77									
196	42350	5340	40-77									
197	42350	5340	56-77									
198	42350	5340	50-77									
199	43947	5101	71-77	43973	4933	57-71						
200	43981	5020	76-77	43977	5069	50-76						

TABLE I

CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
201	43902	5045	68-77									
202	44034	4984	69-77	44011	4983	57-69						
203	43984	5066	68-77									
204	43977	5059	46-77									
205	43999	5031	76-77	43988	5029	75-76	43964	5176	50-75			
206	43761	5150	75-77	38360	-7590	40-75						
207	43918	5010	56-77									
208	43968	4825	71-77	43984	4978	68-71	44054	4930	63-68	42140	6560	-63
209	44022	4978	56-77									
210	44047	4979	70-77	44072	4975	69-70	44028	5081	67-69	44047	4979	-67
211	43988	4966	72-77	42350	5340	67-72	43954	5024	56-67			
212	44300	4770	69-77	42000	6000	54-69						
213	43912	5021	67-77	43923	5018	56-67						
214	43962	5018	56-77									
215	43984	4875	58-77	43970	4922	52-58						
216	43935	5131	73-77	39740	3230	72-73	43935	5131	51-72			
217	INTERVIEW NOT OBTAINABLE											
218	41630	5190	56-77									
219	43450	7560	69-77	43290	9720	63-69	43895	5001	61-63	43540	7560	21-61
220	42350	5340	56-77									
221	43951	5024	56-77									
222	43969	5113	72-77	43982	5097	56-72						
223	44039	4995	56-77									
224	43983	4971	70-77	44025	4998	55-70						
225	44003	4893	59-77	43998	5068	28-59						
226	43982	5043	39-77									
227	42350	5340	56-77									
228	43986	5032	46-77									
229	43983	4952	70-77	43980	4971	56-70						
230	44011	4966	67-77	44033	5027	62-67	43972	5111	56-62			
231	43971	4967	56-77									
232	43965	5072	67-77									
233	43965	5023	61-77	43964	5024	60-61	43966	5026	50-60			
234	43932	5026	56-77									
235	42350	5340	19-77									
236	43850	4998	66-77	44015	5049	55-66						
237	44010	5490	56-77									
238	44985	6510	56-77									
239	43978	5016	70-77	43982	5017	67-70	43891	5099	63-67	42040	6280	61-63
240	43982	5033	72-77	43000	5150	67-72	43982	5033	59-67	54850	7920	40-59

TABLE I

CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
241	43983	5014	56-77									
242	44013	4959	56-77									
243	43971	4909	68-77	53140	29540	12-68						
244	31000	27610	56-77									
245	44720	4740	45-77									
246	INTERVIEW NOT OBTAINABLE											
247	43937	5068	58-77									
248	43950	5106	68-78	43980	5075	42-68						
249	44083	4925	74-78	44088	4973	66-74	45890	24750	50-66			
250	43892	4831	60-77	43947	4980	56-60						
251	44126	4917	73-77	43974	5064	72-73	43985	5041	71-72	43400	13350	49-71
252	44060	4943	71-78	42110	2660	45-71						
253	43000	5150	48-78									
254	43210	5610	34-78									
255	43000	5150	40-78									
256	44287	4753	74-77	44307	5170	70-74	44307	5170	67-70	44040	4882	65-67
257	42350	5340	20-78									
258	43000	5150	37-78									
259	43000	5150	45-78									
260	44019	4898	75-78	43990	5053	45-75						
261	44025	4955	62-78	43970	5007	52-62						
262	44082	4925	56-78									
263	44101	5001	73-78	44920	4920	72-73	44055	4987	51-72			
264	44090	4971	76-78	44150	-10370	74-76	44092	4965	54-74			
265	44025	4968	56-78									
266	43000	5150	55-78									
267	43000	5150	75-78	43450	3890	26-75						
268	44150	7700	45-78									
269	43000	5150	70-78	44150	22850	57-70						
270	43000	5150	77-78	38480	7470	60-77	39620	-7610	30-60			
271	43000	5150	19-78									
272	43000	5150	12-78									
273	43000	5150	75-78	52950	29020	47-75						
274	43000	5150	44-78									
275	43954	4999	68-78	43948	4976	56-68						
276	43831	5033	63-78	99999	4830	-63						
277	43953	5130	61-78	46320	29640	56-61						
278	43000	5150	74-78	43000	5150	63-74	95770	78550	61-63	43000	5150	56-61
279	43000	5150	77-78	54850	7920	74-77						
280	43000	5150	30-78									

TABLE I

CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
281	43000	5150	40-78									
282	43950	4994	52-78									
283	43982	5027	75-78	43975	5018	73-75	43971	5032	44-73			
284	43873	5008	55-78									
285	42820	5260	12-78									
286	43933	5035	63-78	43980	5130	53-63						
287	44010	4933	55-78									
288	43975	5067	73-78	43918	5052	56-73						
289	43995	4926	68-78	43986	4926	43-68						
290	INTERVIEW NOT OBTAINABLE											
291	44021	4982	41-78									
292	42350	5340	56-78									
293	42350	5340	66-78	42350	5340	62-66	42180	6000	56-62			
294	43000	5150	72-78	44090	4969	66-72	95770	78550	63-66	42650	4120	44-63
295	43000	5150	44-78									
296	43000	5150	47-78									
297	43000	5150	61-78	38320	-7680	55-61	46960	32110	50-55			
298	42350	5340	42-78									
299	43000	5150	57-78									
300	42180	7080	42-78									
301	43943	5047	56-78									
302	43916	5069	71-78	43981	5057	67-71	43939	4992	63-67	43983	5018	61-63
303	43968	4826	73-78	43982	4883	47-73						
304	44073	4987	58-78	44094	4969	56-58						
305	44040	4981	70-78	44038	4975	69-70	44038	4981	51-69			
306	44290	4760	40-78									
307	43975	5068	76-78	43979	5012	46-76						
308	43000	5150	69-78	40830	13950	45-69						
309	43000	5150	30-78									
310	43000	5150	42-78									
311	43206	5610	44-78									
312	43000	5150	50-78									
313	43000	5150	50-78									
314	42350	5340	40-78									
315	42820	5260	77-78	44012	4959	50-77						
316	42350	5340	24-78									
317	41640	5190	58-78									
318	42550	4800	76-78	41470	4230	46-76						
319	43000	5150	72-78	48960	32110	62-72						
320	43000	5150	62-78	52480	27720	21-62						

TABLE I

CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
321	44205	4937	74-78	44149	5020	70-74	46550	18420	30-70			
322	43968	4826	76-78	44015	4812	54-76						
323	44061	4943	77-78	44065	4971	52-77						
324	44048	4917	66-78	45130	-1190	63-66	34600	3150	50-63			
325	43984	4998	70-78	43984	4998	69-70	42350	5340	68-69	43984	4998	50-68
326	43982	5011	71-78	43982	5008	61-71	34890	15860	-61			
327	43938	4993	73-78	46300	12850	50-73						
328	42550	4800	55-78	43000	5150	45-55						
329	43000	5150	49-78									
330	43000	5150	69-78	37140	24100	64-69	34620	-670	61-64			
331	43820	14220	30-78									
332	43830	8490	60-78	41320	12600	25-60						
333	43992	4927	76-78	43967	5006	51-76						
334	43000	5150	76-78	46840	20090	45-76						
335	31000	27600	64-78	38190	-7950	62-64	95770	78550	57-62			
336	43000	5150	46-78									
337	43000	5150	77-78	43000	5150	55-77						
338	43968	5021	43-78									
339	43993	5033	62-78	44005	5022	21-62						
340	43963	5007	56-78									
341	43000	5150	71-78	44180	6820	65-71	43000	5150	35-65			
342	43000	5150	46-78									
343	43000	5150	45-78									
344	42430	4980	53-78									
345	43000	5150	40-78									
346	43998	5119	47-78									
347	42350	5340	56-78									
348	43000	5150	77-78	49200	23670	70-77	40614	23826	32-70			
349	43000	5150	44-78									
350	43000	5150	48-78									
351	43000	5150	11-78									
352	43000	5150	58-78	44150	22020	35-58						
353	42350	5340	67-78	42680	3320	43-67						
354	43000	5150	58-78	43992	5119	54-58						
355	43000	5150	74-78	48960	32110	4-74						
356	43000	5150	40-78									
357	43500	6500	40-78									
358	43000	5150	61-78	44150	17030	48-61						
359	43000	5150	74-78	37250	-7120	63-74	42360	11490	57-63			
360	42430	4980	40-78									

TABLE I

CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
361	43000	5150	42-78									
362	43919	5036	48-78									
363	43971	5032	38-78									
364	44013	4988	75-78	44026	4961	70-75	43000	5150	43-70			
365	43954	5032	64-78	43962	5026	62-64	34600	3150	57-62			
366	44013	4981	64-78	44013	4976	46-64						
367	43954	5012	56-78									
368	43000	5150	73-78	35850	19210	71-73	37100	-7380	49-71			
369	43100	5070	45-78									
370	43000	5150	76-78	31980	10500	74-76	41950	10880	64-74	43400	13350	45-64
371	43000	5150	40-78									
372	43300	5070	63-78									
373	41910	3300	45-78									
374	43945	5047	59-78	43973	5032	56-59						
375	44018	4950	68-78	43977	5066	66-68	53400	520	65-66	44017	4878	56-65
376	44005	4981	77-78	43952	4977	64-77	43973	4972	50-64			
377	44023	4987	66-78	44007	4985	50-66						
378	43989	5015	64-78	49680	4830	60-64	49440	9270	10-60			
379	43938	5050	60-78	43964	5067	58-60	43965	5069	50-58			
380	43000	5150	63-78	95770	78550	60-63	43000	5150	51-60			
381	43000	5150	49-78									
382	43000	5150	77-78	36430	18210	9-77						
383	43000	5150	58-78	52190	14410	45-58						
384	43982	5025	71-78	43980	5025	51-71						
385	40973	5993	45-78									
386	42550	4800	46-78									
387	39900	15490	45-78									
388	43000	5150	51-78									
389	43000	5150	23-78									
390	43923	5061	75-78	43870	4730	74-75	43995	4891	73-74	45340	18390	45-73
391	43994	5024	70-78	44187	5115	56-70						
392	44025	4934	56-78									
393	44019	4398	60-78	43630	3095	12-60						
394	44048	4915	69-78	43953	4896	49-69						
395	44064	4821	72-78	43997	4826	62-72	44001	4809	53-62			
396	43976	4969	68-78	44012	4988	60-68	43999	4971	51-60			
397	44006	4949	52-78									
398	44067	4897	76-78	48160	19800	69-76	48160	19800	56-69			
399	44020	4911	65-78	53150	29540	57-65	95770	78550	55-57			
400	43921	5058	77-78	43983	5027	72-77	43977	5031	52-72			

TABLE I

CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
401	44057	4885	64-78	44127	5043	55-64						
402	43983	5037	46-78									
403	44570	6170	74-78	44666	5875	54-74						
404	44016	5057	56-78									
405	43985	5099	77-78	43977	5059	75-77	95770	78550	56-75			
406	44169	4995	63-78	38360	-7590	59-63						
407	43966	5047	56-78									
408	43866	4893	72-78	44012	4955	70-72	43947	5036	69-70	44810	12340	45-69
409	43999	5029	66-78	44008	5021	64-66	43979	4983	60-64			
410	43892	5168	75-78	43872	5102	73-75	44050	5140	71-73	43860	5000	63-71
411	43851	5005	75-78	44009	4937	73-75	43982	5017	68-73	44008	5063	61-68
412	44113	5006	57-78									
413	43984	5056	66-78	40820	9580	45-66						
414	44470	4910	76-78	44410	4910	74-76	44250	4890	54-74			
415	43970	5017	73-78	43931	5012	67-73	43983	5027	65-67	43974	5030	50-65
416	43943	5007	68-78	43958	5027	56-68						
417	44002	5014	56-78									
418	43968	5008	74-78	43967	5008	71-74	44025	4965	56-71			
419	43988	4887	75-78	44027	4963	69-75	44021	4987	63-69	44024	4985	56-63
420	43988	4887	74-79	44027	4963	73-74	43962	5011	62-73	43000	5150	-62
421	43933	5072	69-78	44150	-11170	53-69						
422	44011	5059	76-78	43984	5024	74-76	43923	5022	56-74			
423	INTERVIEW NOT OBTAINABLE											
424	44003	5052	56-78									
425	43950	4760	76-79	44000	4954	54-76						
426	44023	5049	73-79	44008	5034	63-73	44000	5031	61-63	43999	5025	59-61
427	43915	5073	76-79	43400	13350	56-76						
428	43909	5012	58-79	49180	18650	40-58						
429	43998	5125	75-79	44100	4982	73-75	43989	5021	72-73	44053	4954	53-72
430	43000	5150	64-78	41950	10880	49-64						
431	42890	4850	64-78									
432	43000	5150	3-78									
433	43000	5150	91-78									
434	43000	5150	66-78	95770	78550	65-66	43000	5150	55-65	95770	78550	52-55
435	43000	5150	70-78	43410	5400	30-70						
436	43000	5150	77-78	37110	24180	60-77	43000	5150	40-60			
437	43000	5150	45-78									
438	43320	5790	35-79									
439	44082	4937	74-79	44057	4889	73-74	43943	5062	61-73	43990	5029	45-61
440	43970	5069	37-79									

TABLE I

* CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
441	44061	4915	66-79	44056	4917	59-66	44290	4775	58-59	44150	30570	56-58
442	44176	5026	72-79	47470	23660	61-72						
443	44460	4910	40-79									
444	44025	5042	78-79	43998	5063	56-78						
445	43966	4865	72-79	52880	27720	52-72						
446	44078	5003	68-79	44069	5009	66-66	44115	5039	56-66			
447	43968	5059	45-79									
448	43977	5000	55-79									
449	42120	6120	66-79	40810	13100	17-66						
450	41950	10860	10-79									
451	43000	5150	45-79									
452	43000	5150	65-79	48960	32110	57-65						
453	43999	5016	74-79	43978	5051	71-74	43996	5027	69-71	44013	5076	66-69
454	43969	4934	69-79	49660	4830	16-69						
455	43973	5005	58-79	44022	4996	55-58						
456	44152	5003	71-79	44012	4995	65-71	37320	-2000	50-65			
457	43000	5150	78-79	38360	-7590	38-78						
458	42550	4800	45-79									
459	43000	5150	74-79	48400	28910	40-74						
460	41720	3810	76-79	43000	5150	73-76	41720	3810	51-73			
461	43020	5070	40-79									
462	42550	4800	70-79	47900	26100	32-70						
463	43450	3890	45-79									
464	43000	5150	77-79	48460	29280	70-77	46540	18410	65-70	38360	-7590	60-65
465	42350	5340	46-78									
466	42120	6120	38-78									
467	42320	5580	72-78	50500	22280	64-72						
468	43938	5031	58-79	43934	5043	52-58						
469	43986	5033	76-79	43983	5043	64-76	43400	13350	-64			
470	44030	4986	64-79	44093	4962	33-64						
471	43979	5085	59-79	44149	5012	56-59						
472	44073	4976	56-79									
473	43985	5017	56-79									
474	43977	5012	59-79	43937	5051	56-59						
475	43920	5042	73-79	43933	5041	72-73	45890	24700	45-72			
476	43973	5029	68-79	43982	5032	39-68						
477	44012	4953	72-79	44041	4980	56-72						
478	43000	5150	42-79									
479	43000	5150	46-79									
480	43000	5150	37-79									

TABLE I

CASE	MOST RECENT RESIDENCE			NEXT MOST RECENT			NEXT MOST RECENT			NEXT MOST RECENT		
	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD	N-COORD	E-COORD	PERIOD
481	43000	5150	03 14-79									
482	43000	5150	70-79	43916	5037	65-70	52680	12160	38-65			
483	42350	5340	78-79	43000	5150	73-78	43981	5056	56-73			
484	43000	5150	60-78	44150	-10370	58-60						
485	43966	5008	64-79	43995	4993	60-64	44197	4918	56-60			
486	44093	4973	77-79	44300	4770	71-77	38360	-7590	69-71	45530	8630	56-69
487	44015	4980	53-79									
488	41300	2460	64-79	41365	7390	57-64	41230	2690	55-57			
489	43898	5028	76-79	44123	5020	70-76	43970	5130	60-70	43898	5028	-60
490	43979	4970	78-79	41170	4620	23-78						
491	43883	5008	62-79	43882	5013	50-62						
492	INTERVIEW NOT OBTAINABLE											
493	44920	4930	40-79									
494	43000	5150	45-79									
495	43000	5150	53-79	44560	6000	52-53	43000	5150	45-52			
496	42820	5260	73-79	44150	8970	0-73						
497	43000	5150	39-79									
498	43000	5150	48-79									
499	43000	5150	78-79	38360	-7590	62-78	54120	32210	45-62			
500	43000	5150	48-79									
501	43000	5150	60-79	47120	21670	54-60						
502	43976	5040	43-79									
503	43896	5040	56-79									
504	41170	4620	56-79									
505	43921	5058	74-79	43984	4918	66-74	43470	6130	64-66	43963	4926	50-64
506	44360	5310	38-79									
507	44080	5066	75-79	38820	7320	42-75						
508	43995	5152	70-79	37250	-7120	56-70						
509	43823	4991	76-79	43898	4983	74-76	43957	4932	71-74	49930	26410	39-71
510	43000	5150	77-79	38360	-7590	45-77						
511	43000	5150	45-79									
512	43000	5150	46-79									
513	43310	5720	16-79									
514	42350	5340	70-79	43000	5150	50-70	42990	5670	30-50			
515	41150	5440	31-79									
516	42350	5340	68-79	44150	-10340	63-68	42350	5340	40-63			
517	42350	5340	56-79									
518	43900	5066	56-79									
519	44085	4844	75-79	44012	4875	74-75	44085	4844	72-74	44103	4896	67-72

PATHOLOGICAL DATA

The purpose of recording the pathological diagnoses was to find out whether various pathological conditions might have influenced the amount of plutonium burden, or the concentration of plutonium in the tissues. These data were not collected for, and would be ill-suited for, a study seeking evidence whether plutonium burden may have been a causative factor in various pathological conditions. The chief reason for this is that the most important plutonium releases into the air from Rocky Flats evidently occurred during the period 1968-70 (Seed, 1971), although fallout plutonium has been accumulating since the 1940's. The latency period is 15 to 30 years for most radiation-induced cancers; however, by the time of death in 1975-79, only five to ten years would have elapsed for most of our subjects. On the other hand, if the fire at Rocky Flats in 1957 caused plutonium exposure to local residents which was large in comparison with the total plutonium exposure from worldwide fallout, then an excess of radiation-induced cancers might be expected by now among those who lived downwind from Rocky Flats in 1957.

The distribution of causes of death, as coded on the death certificates of our study population, could properly be compared with the distribution of causes of death for the whole state of Colorado for the same period of years, in order to give an indication of the degree to which our population is representative of the population of people who died in Colorado during those years; and this was the reason for collecting these data.

It should be noted that the autopsy cases utilized for this study were not selected in a systematic way, nor in a random way. The staff of the fifteen hospitals involved in the study made the decisions on which cases would have postmortem examinations. We only asked that for inclusion in our study, the individuals should have lived in eastern Colorado for most of the time since 1968 and that they should neither have worked at Rocky Flats nor been otherwise occupationally exposed to plutonium. The few cases for which these criteria were not adhered to were not included in our statistical analyses of the relationships between plutonium burden (or Pu 240/239 ratio) and place of residence.

The autopsy cases whose tissues were submitted to this study were selected for various reasons by the hospital staff physicians. In all but one hospital, a special tissue retention permission form had to be signed by the next of kin before the tissue could be retained for our study. In some cases the physicians or pathologists were particularly interested in studying the tissues, and therefore did not submit the specimens to us. In a few cases, the family knew about our study and specifically requested that an autopsy be performed and that the tissues be submitted to us.

All-in-all, therefore, the selection of cases was not systematic except that we attempted to get roughly equal and sufficiently large numbers of cases from each of the three areas under study: A = the area less than 25 km from Rocky Flats; B = the area 25-50 km from Rocky Flats, and C = the area in eastern Colorado over 50 km from Rocky Flats.

In order to be able to compare the distribution of causes of death in our sample with the distribution in the state of Colorado as a whole, we acquired a copy of the death certificate for each individual in the study. The underlying cause of death had been coded in the normal way on the death certificates by the Colorado State Department of Health, Vital Statistics Division. For deaths occurring before 1979, they used the 8th revision of the International Classification of Diseases; for deaths from 1 January 1979 on they used the 9th revision. We did not recode them all according to one system, because then they would not have been comparable to the Colorado vital statistics.

Table 2 shows the code of underlying cause of death for each individual. The number "8" under ICD code indicates that the 8th revision was used, and the number "9" indicates the 9th revision. The last digit is left blank (-) when the disease was not specified to the degree necessary for the fourth digit to be determined.

Dr. John Berg, Professor of Pathology and Cancer Epidemiologist at UCMC reviewed the final autopsy reports and classified them according to the 3 digit scheme described below. The purpose of this scheme is to allow statistical analysis of how the concentration of plutonium in the tissues may have been influenced by the presence in these organs of various pathological conditions found at autopsy. These data were not collected for the purpose of studying the possibility that the plutonium burden may have been an underlying cause of any pathological conditions, and would be ill-suited for that purpose, as explained above. (See Collection of Tissue under Section 2.)

In Table 2 the pathological conditions mentioned in the summary of the final report are classified according to the presence or absence of various types of tumors (Column 1), lung pathology (Column 2), and liver pathology (Column 3), giving a 3 digit code consisting of a letter or a blank (Column 1), and two numerals (Columns 2 and 3). This is a first attempt at grouping the various pathological conditions in such a way as to have possible relevance to the concentration of plutonium in the lung or liver; or relevance to the total amount of plutonium deposited in the lung or liver.

Classification of Pathological Data for Table 2

COLUMN 1 (Cancer)

The first letter (Column 1) indicates the presence or absence of various types of tumors or cancers. If no tumor or cancer was reported in the autopsy protocol, this is shown by a blank in the first column.

The letters have the following meaning:

A = Tumor or cancer as a major diagnosis and presumed underlying cause of death.

B = Tumor or cancer found at autopsy, but its importance at time of death is indeterminate. (A review of the entire autopsy protocol on these cases would probably reveal further information regarding the importance and the extent of the tumor.)

C = Latent tumor or cancer, or tumor or cancer in the remote past.

D = Tumor or cancer in only one lung (and not a major cause of death) including metastatic cancer in one lung but not the other. (In these cases, the pathologist generally submitted the lung which did not have the tumor or cancer to be analysed for plutonium burden determination.)

COLUMN 2 (Lung Pathology)

The numerals in column 2 refer to various types of lung pathology coded as follows:

0 = When the autopsy protocol did not mention any pathological condition in the lung; or when the conditions mentioned were only acute congestion and/or edema which was evidently only present shortly before the time of death and could not have influenced the amount of plutonium in the lungs.

1 = Primary tumor or metastatic cancer in the lungs. (This code includes other pathological conditions mentioned together with lung tumor or cancer.)

2 = Mild chronic obstructive pulmonary disease (COPH). Without other conditions that would have been coded as 5 or 9.

3 = Moderate COPD or COPD not quantitated. Without other conditions that could have been coded as 5 or 9.

4 = Severe COPD. Without other conditions that would have been coded as 5 or 9.

5 = Other specific lung diseases of over 5 years duration.

6 = Mild COPD. Plus other conditions which would have been coded as 5 or 9 in the absence of COPD.

7 = Moderate COPD. Plus other conditions which would have been coded as 5 or 9 in absence of COPD.

8 = Severe COPD. Plus other conditions which would have been coded as 5 or 9 in absence of COPD.

9 = Reasonably short-term pulmonary disease, generally less than 5 years duration, such as pneumonia, chronic pulmonary edema or pulmonary infarcts.

(Note: pulmonary arteriosclerosis is not included in either 5 or 9 above.)

Column 2 thus amounts to a two dimensional code. It identifies the degree of severity of COPD, if present; and it identifies other conditions if they are also present. This can best be understood diagramatically as follows:

SCHEME FOR CODE NUMBERS FOR PATHOLOGICAL CONDITIONS IN THE LUNG

Pulmonary conditions other than COPD	Severity of COPD			
	None	Mild	Moderate	Severe
None	0	2	3	4
Cancer	1	1	1	1
Others >5 yrs.	5	6	7	8
Others <5 yrs.	9	6	7	8

COLUMN 3 (Liver Pathology)

The numerals in column 3 refer to various types of liver pathology, coded as follows:

0 = When the autopsy protocol did not mention any pathological condition of the liver which conceivably might have influenced the total amount or the concentration of plutonium deposited or retained in the liver.

1 = Primary tumor or metastatic cancer in the liver. (This code includes other pathological conditions mentioned together with the liver tumor or cancer, but such other conditions were mentioned in only a very few cases.)

2 = Includes the following conditions which would cause the liver to be congested and larger than normal at the time of death: acute congestion, chronic congestion, passive congestion, centrilobular necrosis, and centrilobular atrophy.

3 = Fatty metamorphosis.

4 = Both 2 plus 3 above.

5 = Includes conditions which would cause the liver to be smaller than normal at the time of death: micronodular cirrhosis, alcoholic portal fibrosis, cirrhosis not otherwise specified, portal cirrhosis, alcoholic cirrhosis, Laennec's cirrhosis, and nutritional cirrhosis.

6 = Other fibroses and cirrhoses: portal fibrosis, focal fibrosis, fibrosis (resolving alcoholic hepatitis), cardiac cirrhosis, postnecrotic cirrhosis, post hepatitis cirrhosis, secondary biliary cirrhosis, hemosiderosis with fibrosis, cirrhosis of Alpha I antitrypsin deficiency and biliary cirrhosis.

7 = Infections and inflammation: alcoholic hepatitis, focal necrosis, periportal inflammation fibrosis, fulminant hepatitis, pericholangitis (mild), fungal granulomas, and acute necrotizing vasculitis.

8 = Other conditions including: focal infarcts, cholestasis, petechial hemorrhages (microthrombi), cloudy swelling, calcified granulomas, hypervitaminosis A hepatomegaly, and focal nodular hyperplasia.

9 = Various combinations of above groups other than 2 plus 3.

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
1	00	2509	8
2	80	0190	8
3	02	4121	8
4	A11	174-	8
5	90	450-	8
6	A91	1978	8
7	32	492-	8
8	A10	1621	8
9	D00	1621	8
10	00	4319	8
11	32	9503	8
12	00	4123	8
13	A00	191-	8
14	90	5193	8
15	42	5193	8
16	92	4270	8
17	92	4109	8
18	A90	2000	8
19	00	4410	8
20	45	5193	8
21	92	450-	8
22	04	4109	8
23	92	4109	8
24	90	6199	8
25	42	492-	8
26	A11	2070	8
27	A90	4319	8
28	90	4276	8
29	53	614-	8
30	60	470-	8
31	47	5193	8
32	A13	185-	8
33	A90	185-	8
34	90	4123	8
35	A11	1538	8
36	93	3479	8
37	00	4123	8
38	A11	1560	8
39	80	471-	8
40	90	886-	8

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
41	50	4123	8
42	40	4109	8
43	A01	1579	8
44	00	4367	8
45	92	916-	8
46	40	4270	8
47	D90	1621	8
48	95	486-	8
49	C80	5193	8
50	70	492-	8
51	B66	5900	8
52	A71	1579	8
53	02	4109	8
54	D60	1621	8
55	04	2509	8
56	A91	1541	8
57	90	5770	8
58	C90	486-	8
59	60	4370	8
60	99	884-	8
61	02	4109	8
62	95	4410	8
63	92	4123	8
64	C90	4379	8
65	A11	174-	8
66	B90	1991	8
67	A11	4123	8
68	04	4109	8
69	A11	1621	8
70	90	7468	8
71	00	4109	8
72	A11	2059	8
73	A10	174-	8
74	02	5609	8
75	62	1621	8
76	90	4109	8
77	A91	2050	8
78	49	284-	8
79	92	486-	8
80	90	4100	8

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
81	B80	4109	8
82	D81	1621	8
83	A01	4123	8
84	A10	1519	8
85	D01	1621	8
86	D91	1621	8
87	A10	1621	8
88	92	4100	8
89	24	4109	8
90	C00	4109	8
91	76	4123	8
92	07	5699	8
93	A11	1550	8
94	A41	188-	8
95	D00	1621	8
96	A00	1538	8
97	A01	2040	8
98	X	4109	8
99	A11	1621	8
100	72	887-	8
101	B00	2509	8
102	92	3479	8
103	00	8199	8
104	00	3459	8
105	79	570-	8
106	90	7340	8
107	D82	1621	8
108	00	4109	8
109	A31	174-	8
110	A11	174-	8
111	B05	1579	8
112	90	4379	8
113	05	5710	8
114	04	4109	8
115	A92	191-	8
116	33	4109	8
117	A90	2021	8
118	90	4369	8
119	00	4379	8
120	70	4123	8

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
121	00	4109	8
122	35	450-	8
123	A30	5310	8
124	00	4123	8
125	B00	4123	8
126	A23	301-	8
127	83	5193	8
128	32	5193	8
129	93	3004	8
130	80	492-	8
131	A90	2022	8
132	40	4123	8
133	A11	1951	8
134	A11	1579	8
135	32	4122	8
136	00	4123	8
137	00	4109	8
138	92	4109	8
139	90	4339	8
140	02	884-	8
141	02	4122	8
142	A00	450-	8
143	30	2699	8
144	A11	1579	8
145	48	492-	8
146	00	4123	8
147	A92	1830	8
148	35	4123	8
149	40	4379	8
150	00	4109	8
151	70	491-	8
152	97	447-	8
153	D90	1621	8
154	40	5193	8
155	30	4109	8
156	90	4310	8
157	45	5193	8
158	A50	2001	8
159	82	4309	8
160	05	5719	8

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
161	B32	3959	8
162	30	4409	8
163	00	4369	8
164	B02	4109	8
165	92	4519	8
166	30	4109	8
167	56	490-	8
168	40	5193	8
169	A08	5741	8
170	29	485-	8
171	95	887-	8
172	90	450-	8
173	93	5710	8
174	B90	354-	8
175	A19	517-	8
176	D95	1621	8
177	02	4109	8
178	92	7466	8
179	90	486-	8
180	40	4123	8
181	A90	191-	8
182	00	4109	8
183	A11	1621	8
184	92	4109	8
185	00	4123	8
186	A60	4319	8
187	B80	5193	8
188	00	425-	8
189	90	4109	8
190	B80	402-	8
191	A03	1538	8
192	95	5719	8
193	72	4369	8
194	92	4123	8
195	60	2500	8
196	A00	5679	8
197	93	958-	8
198	90	5400	8
199	00	4109	8
200	D91	1890	8

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
201	40	492-	8
202	A91	1550	8
203	A91	201-	8
204	A90	2254	8
205	90	5609	8
206	A90	2000	8
207	50	450-	8
208	A11	251-	8
209	B95	2869	8
210	97	575-	8
211	50	5602	8
212	92	4409	8
213	B50	208-	8
214	B90	4123	8
215	A93	1602	8
216	A11	1630	8
217	00	4109	8
218	35	4442	8
219	72	7123	8
220	92	4109	8
221	60	4109	8
222	60	5769	8
223	B90	2022	8
224	A91	1519	8
225	D00	4109	8
226	50	517-	8
227	54	2509	8
228	A50	4124	8
229	90	4109	8
230	96	5699	8
231	A11	1991	8
232	56	426-	8
233	D91	1621	8
234	90	2251	8
235	05	2509	8
236	A11	1621	8
237	29	2869	8
238	02	442-	8
239	95	4123	8
240	90	4319	8

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
241	85	5710	8
242	90	4109	8
243	00	4109	8
244	A99	1538	8
245	A92	203-	8
246	95	5719	8
247	70	4272	8
248	00	4123	8
249	C90	486-	8
250	32	0389	8
251	00	402-	8
252	00	6824	8
253	02	7468	8
254	00	4109	8
255	A90	1719	8
256	B05	911-	8
257	A90	1579	8
258	D70	486-	8
259	80	5641	8
260	75	492-	8
261	32	4123	8
262	00	1533	8
263	98	4465	8
264	83	493-	8
265	00	4109	8
266	66	575-	8
267	A00	1621	8
268	92	4309	8
269	65	4369	8
270	A12	1890	8
271	72	582-	8
272	A11	1541	8
273	A12	180-	8
274	02	4109	8
275	97	486-	8
276	B92	4462	8
277	72	486-	8
278	A61	1579	8
279	50	4389	8
280	06	3960	8

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
281	92	5770	8
282	69	4123	8
283	A11	1621	8
284	A90	203-	8
285	02	5694	8
286	A11	1719	8
287	C76	4121	8
288	92	4519	8
289	80	5193	8
290	A91	2050	8
291	A16	1579	8
292	95	535-	8
293	98	5400	8
294	A11	186-	8
295	00	4100	8
296	40	491-	8
297	A70	150-	8
298	A72	203-	8
299	70	2509	8
300	63	4123	8
301	52	481-	8
302	00	4123	8
303	40	5193	8
304	92	486-	8
305	46	5193	8
306	50	1409	8
307	A20	1830	8
308	A90	203-	8
309	40	491-	8
310	A72	486-	8
311	A11	150-	8
312	30	4123	8
313	00	4109	8
314	A91	2305	8
315	90	4329	8
316	92	2953	8
317	70	4123	8
318	92	4109	8
319	A51	2022	8
320	A01	4412	8

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
321	98	5621	8
322	A11	1621	8
323	82	492-	8
324	02	4109	8
325	96	450-	8
326	75	5710	8
327	B93	4442	8
328	60	4411	8
329	92	4369	8
330	52	4109	8
331	A11	174-	8
332	A12	5699	8
333	75	322-	8
334	B00	4410	8
335	D61	1621	8
336	A11	1621	8
337	A91	5694	8
338	00	4124	8
339	D71	1621	8
340	80	5193	8
341	96	5740	8
342	B50	279-	8
343	02	4123	8
344	D82	1621	8
345	00	4109	8
346	A11	1621	8
347	92	4109	8
348	A71	1579	8
349	40	4109	8
350	A91	1561	8
351	22	4109	8
352	00	4369	8
353	90	486-	8
354	B00	4380	8
355	D90	1621	8
356	50	4123	8
357	32	492-	8
358	77	4109	8
359	A01	174-	8
360	A11	2050	8

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
361	D91	1991	8
362	02	4109	8
363	A11	150-	8
364	00	4109	8
365	92	4272	8
366	95	5694	8
367	00	4442	8
368	90	8199	8
369	A81	150-	8
370	A11	1978	8
371	00	4109	8
372	90	0200	8
373	A72	2755	8
374	A92	2301	8
375	00	0389	8
376	59	4369	8
377	06	4441	8
378	A11	1538	8
379	A11	1538	8
380	A71	1538	8
381	82	4109	8
382	A11	1538	8
383	A09	2070	8
384	20	4109	8
385	92	486-	8
386	92	3849	8
387	B92	4510	8
388	96	398-	8
389	90	450-	8
390	A11	1538	8
391	93	354-	8
392	90	4339	8
393	40	486-	8
394	02	4412	8
395	A10	1681	8
396	93	4309	8
397	90	486-	8
398	73	510-	8
399	55	425-	8
400	00	887-	8

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
401	90	403-	8
402	52	4124	8
403	62	342-	8
404	70	4212	8
405	72	4109	8
406	90	8199	8
407	30	4369	8
408	A98	054-	8
409	06	5719	8
410	A10	201-	8
411	92	485-	8
412	90	955-	8
413	40	5193	8
414	54	4123	8
415	B72	492-	8
416	B03	4369	8
417	45	5699	8
418	82	7824	8
419	52	3032	8
420	40	4140	9
421	95	450-	8
422	A11	174-	8
423	02	4139	8
424	05	4109	8
425	D96	2123	9
426	20	4140	9
427	80	492-	9
428	00	436-	9
429	03	2500	9
430	92	4300	8
431	A51	1579	8
432	D70	1519	8
433	50	4123	8
434	A93	450-	8
435	C90	404-	8
436	A11	174-	8
437	30	4109	8
438	36	5728	9
439	B70	5070	9
440	00	4275	9

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
441	60	4429	9
442	57	5789	9
443	00	410-	9
444	03	8588	9
445	52	2770	9
446	A11	1749	9
447	00	410-	9
448	72	4280	9
449	40	4415	9
450	A10	2050	9
451	92	410-	9
452	A97	2059	9
453	92	4331	9
454	52	5608	9
455	90	3568	9
456	D01	1629	9
457	A36	303-	9
458	03	4149	9
459	92	485-	9
460	A91	2051	9
461	A06	5715	9
462	04	410-	9
463	52	3989	9
464	A12	1629	9
465	72	4123	8
466	30	887-	8
467	90	8160	8
468	30	5829	9
469	B90	4511	9
470	A11	1629	9
471	A11	0384	9
472	A01	1539	9
473	A91	410-	9
474	95	5188	9
475	00	5770	9
476	90	4329	9
477	95	5762	9
478	A90	1889	9
479	A11	1729	9
480	D01	1990	9

TABLE 2

CASE	AUTOPSY, PATH CODE	DEATH CERTIFICATE, UNDERLYING CAUSE OF DEATH	ICD REVISION
481	79	4340	9
482	00	410-	9
483	90	2952	9
484	90	340-	8
485	32	410-	9
486	95	0384	9
487	95	410-	9
488	A11	2875	9
489	94	303-	9
490	A11	1749	9
491	D01	1629	9
492	00	9580	9
493	D81	1629	9
494	A12	1629	9
495	A10	1509	9
496	C90	485-	9
497	62	410-	9
498	A11	1629	9
499	A90	4140	9
500	00	4140	9
501	A11	185-	9
502	70	5698	9
503	90	4140	9
504	A43	1619	9
505	92	3340	9
506	A11	1539	9
507	A00	1729	9
508	A19	1749	9
509	A80	1990	9
510	A90	2041	9
511	A11	1629	9
512	C52	436-	9
513	A01	1539	9
514	90	4039	9
515	03	4373	9
516	93	410-	9
517	90	4151	9
518	A11	1890	9
519	A18	1707	9

TABLE 3

EPIDEMIOLOGICAL DATA

CASE

Consecutive number assigned to a decedent's set of tissue samples.

AGE AT DEATH

Age in years which the decedent had attained at time of death.

SEX

M=Male F=Female

SMOKING HISTORY IN PACK-YEARS

Smoking history obtained by multiplying packs of cigarettes smoked per day multiplied by number of years smoked; 0-indicates the decedent did not smoke, "1" through "97" is the number of pack-years smoked, "98" is greater than or equal to 98 pack-years. Decedents who had smoked "occasionally" were coded as "1" pack year and those for whom a smoking history was not available were coded "99".

EMBALMED BEFORE AUTOPSY

Y=Yes N=No

POSSIBLE OCCUPATIONAL EXPOSURE TO WEAPONS GRADE PLUTONIUM

Decedents were considered to have had a possible occupational exposure to plutonium if they worked at a facility which uses plutonium such as Rocky Flats Nuclear Weapons Plant, Hanford Atomic Workers, etc. or had been involved in weapons testing. Y=Yes, N=No, U=Unknown

(Continued)

TABLE 3 (Continued)

RESIDED ON WESTERN SLOPE

Persons who had resided in places known to be contaminated with plutonium like the South Pacific atom bomb test areas or on the Western Slope of the Rocky Mountains, in Nevada or in Utah during the 50's or 60's were coded as Y=Yes ~~in this column~~, N=No, U=Unknown.

~~In spite of the fact that~~ up until July 1977, the interviewer did not ask for a detailed residence history ~~any~~ farther back than 1968. however, the respondent often volunteered this information, and it was duly recorded. The interviewer ~~did~~ also queried the next of kin to rule out any possible plutonium exposure in places like the South Pacific or the Nevada Test site, at any time. Any such residence in plutonium-contaminated areas would be coded as Y=Yes~~; and if~~ unknown~~, it would be coded~~ OR as U=Unknown i~~n this column~~. For the first 190 cases, where the interview record did not show an answer to this question specifically, the next of kin were recontacted ~~later~~ to check on the accuracy of the coding of this item. Of these 190 cases, there were only 6 cases where the second interview did not substantiate the coding of the first interview. In case 171, ~~it was due to a~~ coding error was at fault (should have been Y=Yes). In cases 28,33,122,136, and 144 the second interview could not confirm that the case had never resided on the Western Slope or in a plutonium-contaminated area. These codings have not been changed in Table 3.

Individuals coded as Y or U may possibly have been exposed to weapons grade plutonium fallout from various atom bomb tests and were therefore not included in the statistical analyses of the relationship between Pu 240/239 isotope ratio and place of residence in relation to Rocky Flats. (See Section 5, discussion of Significance of Plutonium 240/239 Ratios.)

TABLE 3

CASE	AGE AT DEATH	SEX	SMOKING HISTORY IN PACK-YEARS	EMBALMED BEFORE AUTOPSY	POSSIBLE OCCUPATIONAL PU EXPOSURE	RESIDED ON WEST SLOPE
1	62	F	0	N	N	N
2	71	M	15	Y	N	N
3	63	M	30	Y	N	N
4	45	F	25	Y	N	N
5	39	M	30	Y	N	N
6	87	M	97	Y	N	N
7	51	F	45	Y	N	N
8	65	M	60	Y	N	N
9	50	M	60	Y	N	N
10	59	M	13	Y	N	N
11	61	M	90	N	N	N
12	80	F	15	Y	N	N
13	59	F	0	Y	N	N
14	78	M	75	Y	N	N
15	83	F	0	Y	N	N
16	87	F	0	Y	N	N
17	58	F	0	Y	N	N
18	76	M	40	Y	N	N
19	64	M	0	Y	N	N
20	50	M	13	N	N	N
21	81	F	0	Y	N	N
22	65	F	20	Y	N	N
23	38	M	38	N	U	N
24	23	M	99	N	N	N
25	70	M	97	Y	N	N
26	59	M	30	Y	N	N
27	66	M	45	N	N	N
28	47	M	98	Y	N	N
29	32	F	1	Y	N	N
30	82	F	0	Y	N	N
31	63	M	60	N	N	N
32	53	M	60	Y	N	N
33	66	M	68	N	N	N
34	59	F	0	N	N	N
35	73	M	99	N	N	N
36	18	M	1	Y	N	N
37	71	M	0	N	N	N
38	64	M	0	Y	Y	N
39	71	M	18	N	N	N
40	77	F	40	N	N	N
41	75	M	47	N	N	N
42	87	F	0	N	N	Y
43	78	M	97	N	N	N
44	85	M	0	Y	N	N
45	67	M	10	Y	N	N

TABLE 3

CASE	AGE AT DEATH	SEX	SMOKING HISTORY IN PACK-YEARS	EMBALMED BEFORE AUTOPSY	POSSIBLE OCCUPATIONAL PU EXPOSURE	RESIDED ON WEST SLOPE
46	85	M	50	Y	N	N
47	76	M	97	N	N	N
48	62	F	0	Y	N	N
49	75	M	98	N	N	N
50	76	F	60	Y	N	N
51	86	F	0	N	N	Y
52	73	M	45	Y	N	N
53	60	F	15	Y	N	N
54	57	M	70	Y	N	N
55	79	F	0	Y	N	N
56	71	M	97	Y	N	N
57	73	M	47	N	N	N
58	76	F	30	N	N	N
59	90	F	9	Y	N	N
60	83	F	0	Y	N	N
61	52	M	30	Y	N	N
62	64	F	30	Y	N	N
63	82	F	0	Y	N	N
64	86	M	0	N	N	N
65	55	F	30	Y	N	N
66	71	M	97	Y	N	N
67	94	F	0	N	N	N
68	73	M	0	Y	N	N
69	55	M	30	N	N	N
70	56	F	0	Y	N	N
71	79	F	30	N	N	N
72	74	M	60	Y	N	N
73	64	F	0	Y	N	N
74	65	M	0	Y	N	N
75	73	M	65	N	N	N
76	52	F	35	N	N	N
77	51	F	0	Y	N	N
78	84	M	0	Y	N	N
79	47	M	60	Y	N	N
80	47	M	99	Y	N	N
81	68	M	24	Y	N	N
82	58	M	60	Y	N	N
83	82	F	0	Y	N	N
84	63	M	45	Y	N	N
85	75	M	60	Y	N	N
86	77	F	11	Y	N	N
87	63	M	45	N	N	N
88	67	F	0	N	N	N
89	53	M	97	N	N	N
90	62	M	0	N	N	N

TABLE 3

CASE	AGE AT DEATH	SEX	SMOKING HISTORY IN PACK-YEARS	EMBALMED BEFORE AUTOPSY	POSSIBLE OCCUPATIONAL PU EXPOSURE	RESIDED ON WEST SLOPE
91	81	M	30	N	N	N
92	60	M	30	Y	N	N
93	63	M	90	N	N	N
94	73	M	98	Y	N	N
95	69	M	99	N	N	N
96	50	M	99	Y	N	N
97	24	M	99	Y	N	N
98	79	F	0	N	N	N
99	64	M	0	Y	N	N
100	81	M	45	N	N	N
101	61	M	15	Y	N	N
102	61	F	99	N	N	N
103	19	M	0	N	N	N
104	32	M	8	N	N	N
105	65	F	0	Y	N	N
106	46	F	0	Y	N	N
107	56	M	60	N	N	N
108	62	M	99	Y	N	N
109	71	F	98	Y	N	N
110	58	F	98	Y	N	N
111	47	F	0	N	N	N
112	68	F	5	N	N	N
113	55	M	45	N	N	N
114	69	M	99	Y	N	N
115	57	M	0	Y	N	N
116	74	M	30	Y	N	N
117	79	F	0	N	N	N
118	81	F	0	Y	N	N
119	66	M	30	Y	N	N
120	78	M	0	N	N	N
121	48	M	45	N	N	N
122	73	M	60	N	N	N
123	76	M	85	Y	N	N
124	69	M	99	Y	N	N
125	76	F	50	Y	N	N
126	66	M	1	N	N	N
127	60	M	99	N	N	Y
128	76	M	53	N	Y	N
129	53	F	30	N	N	N
130	74	M	68	N	N	N
131	51	M	14	Y	N	N
132	83	M	20	Y	N	N
133	59	M	30	N	N	Y
134	77	F	40	N	N	N
135	65	M	20	Y	N	N

TABLE 3

CASE	AGE AT DEATH	SEX	SMOKING HISTORY IN PACK-YEARS	EMBALMED BE-FORE AUTOPSY	POSSIBLE OCCUPA-TIONAL PU EXPOSURE	RESIDED ON WEST SLOPE
136	73	M	99	Y	N	N
137	73	F	99	Y	N	N
138	67	M	92	N	N	N
139	76	F	99	N	N	N
140	13	M	0	N	N	N
141	72	F	0	Y	N	N
142	74	F	0	Y	N	N
143	74	F	80	Y	N	N
144	67	F	27	Y	N	N
145	51	F	97	Y	N	Y
146	59	M	99	Y	U	U
147	61	F	0	Y	N	N
148	71	M	97	N	N	N
149	71	M	99	N	N	N
150	66	F	68	N	N	N
151	72	F	50	Y	N	N
152	76	F	99	Y	N	N
153	39	F	3	Y	N	N
154	79	F	0	Y	N	N
155	66	M	24	N	N	N
156	61	M	45	Y	N	N
157	63	M	99	N	N	N
158	58	M	99	N	N	N
159	64	M	27	Y	N	N
160	54	M	53	Y	Y	Y
161	87	M	97	N	N	N
162	77	F	80	Y	N	N
163	63	F	0	N	N	N
164	57	M	97	Y	N	N
165	65	M	0	Y	N	N
166	83	M	0	Y	N	N
167	87	F	0	N	N	N
168	56	M	99	Y	N	N
169	66	M	30	Y	N	N
170	54	M	0	N	N	N
171	45	M	30	N	N	N
172	73	M	55	N	N	N
173	32	M	0	N	N	N
174	69	M	0	Y	N	N
175	69	M	99	N	Y	U
176	49	M	99	Y	Y	N
177	74	F	1	N	N	N
178	31	M	34	N	N	N
179	84	F	0	Y	N	N
180	80	M	30	N	N	Y

TABLE 3

CASE	AGE AT DEATH	SEX	SMOKING HISTORY IN PACK-YEARS	EMBALMED BE- FORE AUTOPSY	POSSIBLE OCCUPA- TIONAL PU EXPOSURE	RESIDED ON WEST SLOPE
181	60	M	98	Y	N	N
182	78	F	0	N	N	N
183	49	M	60	N	N	N
184	66	M	97	N	N	N
185	76	F	0	Y	N	N
186	55	F	35	N	N	N
187	70	M	15	N	N	N
188	40	F	23	Y	N	N
189	66	M	40	N	N	N
190	85	M	99	Y	N	N
191	66	F	0	Y	N	N
192	38	M	25	Y	N	N
193	82	F	0	Y	N	N
194	78	M	99	N	N	N
195	84	F	0	N	N	N
196	71	F	5	N	N	N
197	33	M	38	N	N	N
198	60	M	17	Y	N	N
199	69	M	45	Y	N	N
200	77	M	3	Y	N	N
201	70	F	97	N	N	N
202	56	F	0	Y	N	N
203	80	F	0	Y	N	N
204	83	F	0	Y	N	N
205	89	F	0	Y	N	N
206	59	F	0	N	N	N
207	79	M	0	N	N	N
208	24	M	0	Y	N	N
209	80	M	99	Y	N	N
210	29	F	13	Y	N	N
211	85	F	0	Y	N	N
212	66	M	99	N	N	N
213	80	F	0	N	N	N
214	74	F	99	Y	N	N
215	62	M	0	N	N	N
216	56	M	0	N	N	N
217	71	F	99	N	N	N
218	60	F	32	N	U	U
219	56	F	40	Y	N	N
220	56	M	24	N	N	N
221	88	M	0	N	N	N
222	81	F	0	N	N	N
223	65	M	40	Y	N	N
224	92	F	0	Y	N	N
225	71	M	92	N	N	N

TABLE 3

CASE	AGE AT DEATH	SEX	SMOKING HISTORY IN PACK-YEARS	EMBALMED BEFORE AUTOPSY	POSSIBLE OCCUPATIONAL PU EXPOSURE	RESIDED ON WEST SLOPE
226	68	M	40	N	N	N
227	49	M	0	N	N	N
228	81	F	0	Y	N	N
229	84	M	99	N	N	N
230	77	M	0	N	N	N
231	57	F	20	Y	N	N
232	22	M	0	N	N	N
233	68	M	40	Y	N	N
234	64	F	0	Y	N	N
235	58	F	0	N	N	N
236	53	M	48	Y	N	N
237	66	M	0	N	N	N
238	86	M	4	N	N	N
239	64	M	0	Y	N	N
240	61	F	65	N	N	N
241	76	F	99	N	N	N
242	75	M	1	Y	N	N
243	65	M	19	Y	N	N
244	79	F	0	N	N	N
245	61	F	43	N	N	N
246	60	M	99	N	U	U
247	61	M	31	N	N	N
248	76	F	97	Y	N	N
249	80	F	0	N	N	N
250	72	M	97	N	N	N
251	28	F	3	Y	N	N
252	74	M	3	N	N	N
253	53	M	70	Y	N	N
254	62	F	0	Y	N	N
255	78	M	39	Y	N	N
256	47	F	46	N	N	N
257	81	F	0	Y	N	N
258	67	M	45	Y	N	N
259	71	M	44	N	N	N
260	79	F	60	Y	N	N
261	85	M	49	Y	N	N
262	73	M	98	Y	N	N
263	26	F	10	N	N	N
264	52	F	48	Y	N	N
265	75	F	0	Y	N	N
266	80	F	23	Y	N	N
267	52	M	63	Y	N	N
268	54	F	0	Y	N	N
269	79	M	3	Y	N	N
270	57	M	55	Y	N	N

TABLE 3

CASE	AGE AT DEATH	SEX	SMOKING HISTORY IN PACK-YEARS	EMBALMED BE-FORE AUTOPSY	POSSIBLE OCCUPA-TIONAL PU EXPOSURE	RESIDED ON WEST SLOPE
271	58	M	50	Y	N	N
272	65	M	0	Y	N	N
273	54	F	20	Y	N	N
274	82	M	0	Y	N	N
275	69	F	96	N	N	N
276	58	F	0	N	N	N
277	89	F	0	Y	N	N
278	57	M	20	Y	Y	N
279	4	M	0	Y	N	N
280	47	F	0	Y	N	N
281	68	F	44	Y	N	N
282	55	M	45	Y	N	N
283	74	M	55	Y	N	N
284	73	F	0	Y	N	N
285	71	M	0	Y	N	N
286	59	F	0	N	N	N
287	69	M	20	Y	N	N
288	76	M	2	Y	N	N
289	64	M	30	N	N	N
290	30	M	99	N	U	U
291	75	M	75	N	N	N
292	33	M	0	N	N	N
293	56	F	97	N	N	N
294	33	F	10	N	N	N
295	58	M	0	Y	N	N
296	79	F	96	N	N	N
297	75	M	20	N	N	N
298	80	F	0	N	N	N
299	69	F	0	Y	N	N
300	73	F	0	N	N	N
301	66	F	0	Y	N	N
302	84	F	0	Y	N	N
303	69	M	40	N	N	N
304	54	M	35	Y	N	N
305	63	F	60	N	N	N
306	65	F	13	N	N	N
307	90	F	0	Y	N	N
308	82	F	0	Y	N	N
309	83	M	60	Y	N	N
310	77	M	97	Y	N	N
311	60	M	80	Y	N	N
312	79	F	0	Y	N	N
313	50	M	30	Y	N	N
314	61	M	0	N	N	N
315	82	F	0	N	N	N

TABLE 3

CASE	AGE AT DEATH	SEX	SMOKING HISTORY IN PACK-YEARS	EMBALMED BEFORE AUTOPSY	POSSIBLE OCCUPATIONAL PU EXPOSURE	RESIDED ON WEST SLOPE
316	91	F	0	N	N	N
317	88	M	0	Y	N	U
318	71	M	0	N	N	N
319	65	M	32	N	N	N
320	74	M	70	Y	N	N
321	67	M	97	N	N	N
322	66	F	71	N	N	N
323	59	M	41	N	N	N
324	81	M	0	Y	N	Y
325	90	F	0	N	N	N
326	71	F	0	N	N	N
327	77	M	75	Y	N	N
328	74	M	29	Y	N	N
329	62	M	0	Y	N	N
330	57	M	0	N	N	N
331	63	F	0	Y	N	N
332	85	M	20	Y	N	N
333	78	M	97	N	N	N
334	57	M	4	Y	N	N
335	67	M	10	Y	N	N
336	72	M	97	Y	N	N
337	76	F	0	N	N	N
338	90	F	0	N	N	N
339	73	M	15	Y	N	N
340	73	M	43	Y	N	N
341	74	F	0	Y	N	N
342	80	M	40	Y	N	N
343	66	M	0	Y	N	N
344	71	M	75	Y	N	N
345	74	F	0	Y	N	N
346	72	M	57	N	N	N
347	52	M	5	N	N	N
348	45	F	30	N	N	N
349	87	M	70	Y	N	N
350	63	M	20	Y	N	N
351	66	M	90	N	N	N
352	57	M	37	Y	N	N
353	84	M	90	N	N	Y
354	79	F	10	N	N	N
355	74	M	97	Y	N	N
356	69	M	60	Y	N	N
357	72	M	80	Y	N	N
358	48	M	45	Y	N	N
359	42	F	0	Y	N	N
360	58	M	40	N	N	N

TABLE 3

CASE	AGE AT DEATH	SEX	SMOKING HISTORY IN PACK-YEARS	EMBALMED BEFORE AUTOPSY	POSSIBLE OCCUPATIONAL PU EXPOSURE	RESIDED ON WEST SLOPE
361	74	F	0	Y	N	N
362	86	F	0	N	N	N
363	74	M	0	Y	N	N
364	52	F	0	N	N	N
365	61	M	0	N	N	N
366	86	M	25	Y	N	N
367	66	F	69	N	N	N
368	29	M	0	Y	N	N
369	82	F	60	N	N	N
370	43	F	0	N	N	N
371	58	M	0	Y	N	N
372	15	F	0	N	N	N
373	62	M	70	N	N	N
374	76	M	15	N	N	N
375	74	F	0	N	N	N
376	68	M	50	N	N	N
377	74	F	14	N	N	N
378	68	M	42	N	N	N
379	66	F	38	Y	N	N
380	57	F	0	Y	N	N
381	63	M	97	Y	N	N
382	69	M	60	N	N	N
383	57	M	0	Y	N	N
384	78	F	98	Y	N	N
385	66	M	40	N	N	N
386	67	M	0	N	N	N
387	83	M	0	Y	N	N
388	59	F	0	Y	N	N
389	76	F	70	Y	N	N
390	32	M	0	N	N	N
391	73	F	14	Y	N	N
392	69	F	0	N	N	N
393	87	M	6	N	N	Y
394	69	M	99	N	N	N
395	70	M	20	N	N	N
396	70	F	15	Y	N	N
397	26	F	0	N	N	N
398	65	F	97	N	N	N
399	45	M	30	N	N	N
400	88	F	0	N	N	N
401	43	F	1	N	N	N
402	64	F	40	N	N	N
403	75	M	27	N	N	N
404	86	M	60	N	N	N
405	45	M	25	N	N	N

TABLE 3

CASE	AGE AT DEATH	SEX	SMOKING HISTORY IN PACK-YEARS	EMBALMED BE- FORE AUTOPSY	POSSIBLE OCCUPA- TIONAL PU EXPOSURE	RESIDED ON WEST SLOPE
406	19	M	4	N	N	N
407	82	F	53	N	N	N
408	33	M	23	N	N	N
409	18	F	0	N	N	N
410	41	M	0	N	N	N
411	40	F	41	N	N	N
412	21	M	0	N	N	N
413	67	M	20	N	N	N
414	86	F	96	Y	N	N
415	55	F	68	Y	N	N
416	52	M	92	Y	N	N
417	64	F	0	N	N	N
418	76	M	60	N	N	N
419	76	M	15	N	N	N
420	74	M	97	N	N	N
421	68	F	25	N	N	N
422	22	F	3	N	N	N
423	45	M	99	N	U	U
424	81	M	98	N	N	N
425	48	M	97	N	Y	N
426	57	M	50	N	N	N
427	87	M	52	N	N	N
428	78	F	0	N	N	N
429	26	F	11	N	N	N
430	50	M	20	Y	N	N
431	41	M	20	Y	N	N
432	75	F	0	N	N	N
433	91	F	0	Y	N	N
434	58	F	30	N	N	N
435	83	M	20	Y	N	N
436	38	F	0	Y	N	N
437	72	F	50	N	N	N
438	71	M	30	N	N	N
439	92	M	0	Y	N	N
440	75	F	0	N	N	N
441	47	M	40	N	N	N
442	17	F	0	N	N	N
443	60	F	0	N	N	N
444	38	M	3	N	N	N
445	26	M	0	N	N	N
446	57	M	0	N	N	N
447	86	F	98	Y	N	N
448	78	M	38	N	N	N
449	67	M	80	N	N	N
450	68	F	0	Y	N	N

TABLE 3

CASE	AGE AT DEATH	SEX	SMOKING HISTORY IN PACK-YEARS	EMBALMED BEFORE AUTOPSY	POSSIBLE OCCUPATIONAL PU EXPOSURE	RESIDED ON WEST SLOPE
451	66	M	80	Y	N	N
452	21	F	0	N	N	N
453	82	F	38	N	N	N
454	80	F	51	N	N	N
455	67	F	98	Y	N	N
456	51	F	10	N	N	N
457	58	F	40	Y	N	N
458	70	F	0	N	N	N
459	79	F	0	Y	N	N
460	31	M	0	Y	N	N
461	82	M	0	Y	N	Y
462	46	M	30	N	N	N
463	78	F	0	N	N	N
464	48	M	30	N	N	N
465	62	M	98	N	N	N
466	83	F	20	N	N	N
467	14	M	0	N	N	N
468	70	M	80	N	N	N
469	99	F	0	Y	N	N
470	53	M	69	N	N	N
471	77	F	5	N	N	N
472	58	F	1	N	N	N
473	75	F	98	N	N	N
474	63	M	42	N	N	N
475	63	F	40	Y	N	N
476	83	F	16	N	N	N
477	63	M	0	N	N	N
478	75	M	20	Y	N	N
479	66	M	50	Y	N	N
480	42	F	0	Y	N	N
481	65	M	5	Y	N	N
482	66	M	50	N	N	N
483	50	F	4	N	N	N
484	21	M	0	N	N	N
485	71	M	40	N	N	N
486	35	F	98	N	N	N
487	84	F	0	N	N	N
488	69	F	25	N	N	Y
489	48	M	0	N	N	N
490	56	F	0	N	N	N
491	65	M	52	Y	N	N
492	25	M	99	N	U	U
493	67	M	11	N	N	N
494	66	M	40	Y	N	N
495	63	M	40	N	N	Y

TABLE 3

CASE	AGE AT DEATH	SEX	SMOKING HISTORY IN PACK-YEARS	EMBALMED BEFORE AUTOPSY	POSSIBLE OCCUPATIONAL PU EXPOSURE	RESIDED ON WEST SLOPE
496	79	M	40	Y	N	N
497	79	M	25	Y	N	N
498	79	M	97	N	N	N
499	77	F	45	Y	N	N
500	62	M	0	Y	N	N
501	62	M	80	Y	N	Y
502	78	F	0	N	N	N
503	85	F	40	Y	N	N
504	61	F	46	N	N	N
505	36	F	98	N	N	N
506	63	F	0	N	N	N
507	41	M	97	N	N	N
508	68	F	97	N	N	N
509	62	M	30	N	N	N
510	67	F	98	Y	N	N
511	42	F	0	Y	N	N
512	69	M	50	N	N	N
513	62	M	10	Y	N	N
514	75	F	0	N	N	N
515	48	M	38	Y	N	N
516	58	M	38	N	N	N
517	75	F	8	N	N	N
518	50	M	50	Y	N	N
519	12	F	0	N	N	N

DETERMINATION OF PLUTONIUM, LABORATORY ANALYSIS

The McClellan Central Laboratory (MCL) performed the laboratory analyses for plutonium in tissues using both alpha pulse height analysis (APHA) and mass spectrometry (MS). The apparatus and procedure used to analyze the samples are detailed in Appendix H and I.

Preparation and Standardization of the Plutonium 242 Tracer

This work was performed by P.G. Johnson, R.D. Carver, and R.J. Dupzyk of the Lawrence Livermore Laboratory under the auspices of the US Energy Research and Development Administration under contract number W-7405-Eng-48. The high purity Pu 242 tracer was made by enriching 2.162 mg of plutonium oxide, 99.99% Pu 242, in an isotope separator. A small portion of the isotopically enriched plutonium was removed for analysis. Alpha analysis indicated it contained $(1.763 \pm 0.0011) \times 10^{12}$ Pu 242 atoms/ml. Table 4 shows the atom ratio and the calculated alpha ratio of this material (Johnson, 1977).

TABLE 4. ATOM RATIO AND CALCULATED ALPHA ACTIVITY RATIO FOR PU 242 TRACER USED IN STUDY

	Atom Ratio	Calculated Alpha Ratio
Pu 239/Pu 242	$6 \pm 2 \times 10^{-7}$	$9.6 \pm 1.6 \times 10^{-6}$ (2)
Pu 240/Pu 242	$4 \pm 1.6 \times 10^{-7}$	$9.0 \pm 1.2 \times 10^{-5}$

MCL standardized an aliquot of the Pu 242 tracer by comparing it to a gravimetric standard (CAL 16-62) that was prepared from 1.0023 grams of plutonium oxide furnished by Los Alamos Scientific Laboratory. This gravimetric standard was verified by MCL, Los Alamos Scientific Laboratory, Lawrence Livermore Laboratory, and Knolls Atomic Power Laboratory to ± 0.25%.

(2) Throughout this paper, unless otherwise specified, the values following a ± sign indicate one standard deviation for the measurement involved.

Standardization of the Pu 242 tracer was accomplished via alpha spectroscopy and mass spectrometry. Four 30 ml aliquots were standardized by alpha spectroscopy and ten one ml aliquots were standardized by mass spectrometry against CAL 16-62. This standardization yielded the following results:

1. Via APHA: Pu 242 dpm/ml = 3.447 ± 0.29%
2. Via MS: Pu 242 dpm/ml = 3.454 ± 0.32%

The mass spectrometer's ability to measure Pu 240/Pu 239 atom ratios was verified by measuring National Bureau of Standards "Standard Reference Materials" NBS-946 and NBS-948. During the course of analysis of the tissues, MCL received NBS-946 or NBS-948 solutions at least twice yearly from the Rocky Flats Nuclear Weapons Facility as part of the Plutonium Isotope Exchange Program. Analysis of these solutions at MCL always gave Pu 240/239 atom ratios that agreed to within ± 0.25% of the certified National Bureau of Standards value. In addition to the Plutonium Isotope Exchange Program's samples, MCL also analyzed their own standards on a weekly basis to verify that mass spectrometers always measured the atom ratios to within ± 0.25%.

The step-by-step procedure for the chemical separation of plutonium and preparation of specimens for counting on the alpha pulse height spectrometers and the mass spectrometers are given in Appendix H, I and J.

Alpha Spectroscopy

Plutonium samples were analyzed by alpha spectroscopy for the presence of Pu 236, Pu 238 and Pu 239+240. MCL generally counted each sample one time on either a Frisch Grid detector for approximately 2000 minutes or a silicon solid state detector for approximately 3000 minutes, but for various reasons the counting times were occasionally much shorter. Frisch Grid spectrometers are capable of 50 KeV resolution of actual samples electrodeposited on flat, mirror-finished platinum planchets with a counting efficiency greater than 46% and a background less than 0.01 cpm over each designated energy region. The silicon solidstate detectors are capable of 30 KeV resolution with a counting efficiency of 14% and a background less than 0.005 cpm.

The resulting alpha spectrum was resolved (by energy levels) and stored in a Multichannel analyzer. The data from each sample was corrected for machine background and then analyzed by an energy range technique that compensates for "tailing." (See Appendices I and J.) The DPM levels have been decay corrected to 1 January of the year of measurement.

All measurements are reported with their chemical yields and counting errors as calculated from the counting statistics. The chemical yield of the sample was calculated from the net counts of the Pu 242 tracer. The counting error for the DPM value is the coefficient of variation, expressed in percent, as determined by counting statistics (for a single count: standard deviation $= \sqrt{n}$).

Definition of "No Plutonium Detected"

Past practice at MCL had been to quote an "upper limit" value for any plutonium activity determinations for which the difference between the actual plutonium count and the background was small. Specifically, if g is the gross count rate of the sample, b is the appropriate background count rate and S^2_g and S^2_b are their estimated variances, then, under the null hypothesis of the equality of the sample and background count rates,

$$z = \frac{g - b}{\sqrt{S^2_g + S^2_b}}$$

is approximately normally distributed with zero mean and unit standard deviation. If the standard normal variate $z < 2$ (i.e., the estimated standard error of the difference is greater than half of the observed difference) then the null hypothesis cannot be rejected at about the 2% level of statistical testing, the specimen count is regarded as merely reflecting background radiation, and the count for that specimen was reported as an "upper limit" value. Measurements with "upper limit" values were re-run using another aliquot and a longer counting time whenever possible. Discussion of the whole subject of "upper limit" values resulted in the decision by MCL to report all determinations which had only "upper limit" values as "No Plutonium Detected," for the official report of this study,and the actual readings were not made available for this study.

The distribution by magnitude of the "upper limit" values for the first 400 cases in this study was, however, available. (See Figure 6, pg. 137 and the discussion of the problem of counts near background under the Statistical Analysis, Section 4.)

This is a subject which needs further discussion and clarification for future studies. (See Appendix I for details of alpha spectroscopy.)

Mass Spectrometry

Plutonium samples are loaded by evaporation on a rhenium filament, placed in the mass spectrometer's source, and ionized by heating to 1900°C. The mass separated ion beams, each containing a specific isotope of plutonium, are sequentially focused on the detector system by varying the accelerating voltage of the source. The ion beam intensity of each isotope of plutonium is measured for a predetermined amount of time. The extraneous background in the sample is assessed before and after each plutonium isotope beam is measured by quantifying the noise at the half mass position. (Details of mass spectrometry are given in Appendix J.)

Calculation of Plutonium Level in Samples

Since the Pu 242 tracer was thoroughly mixed and equilibrated with the solution containing the sample, the total activity (x) of plutonium isotopes 236,238,239, and 240 (in disintegrations per minute) for each sample, is calculated by adjusting the actual APHA or MS measurement (z) according to the percentage yield of the tracer (y). Thus $x = 100\ z/y$. This calculation has been done to get the activity values shown in all the tables which follow.

The tracer yield is shown in Tables 5 and 6 for each sample analysed. Note that using this tracer method, a high tracer yield is not necessary for a valid determination. A very low tracer yield, however, would decrease the reliability of the measurement.

Contamination Prevention

MCL is an environmental analysis laboratory that routinely handles samples containing nanogram quantities of plutonium. Samples containing larger quantities of plutonium have never been allowed into the laboratory. In order to check for laboratory contamination at MCL, instrument blanks, reagent blanks, and processing blanks were run during the course of analysis.

Instrument blanks on the alpha spectrometers were run biweekly. Background counts were 5000 minutes. The Frisch Grid detectors had backgrounds less than 0.01 cpm (.02 dpm) in the Pu 239+240 region. The silicon solid state detectors had backgrounds less than 0.005 cpm (.04 dpm) in the plutonium energy regions.

Backgrounds on the mass spectrometers were assessed weekly. No mass spectrometer instrument background above 0.02 dpm Pu 239+240 was ever measured.

The plutonium blank in each reagent was assessed before the reagent was used for tissue analysis. No reagent (200 ml aliquot) ever showed plutonium levels above background as defined by instrument blank measurements. Plutonium blanks were run quarterly. A processing blank consisted of running all of the reagents through the plutonium separation chemistry. (See Appendix J.) All processing blanks showed "No Plutonium Detected" as defined on page 63.

In addition, MCL took swipes of the processing and measurement areas. Particles were separated from these swipes, immersed in Collodian, placed on Lexan polycarbonate, and irradiated to check for plutonium. This technique can detect as little as 2×10^{6} atoms of fissile material (U 235, Pu 239) per particle. The particles containing fissile material were analyzed by mass spectrometry. This technique can detect 2×10^{-4} dpm Pu 239 per particle. No positive plutonium contamination was measured on swipes from the processing and measurement areas at MCL.

SECTION 3

RESULTS

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

Table 5 presents the results of Pu 239 plus 240 assay of the 1191 tissue samples and quality assurance samples. The following explains the entries in each column of the table:

Sample Number

Consists of a case number ranging from 1 to 519 followed after the hyphen, by a tissue type number.

Tissue Type

Tissue type for the sample:

2 or 7 = liver
3 or 8 = lung
9 = used in three cases, two are special liver specimens; the other is a sample of blood and/or fluid drained from the liver.

Organ Weight

Weight in grams of the whole liver or whole right or left lung as recorded by the pathologist at time of autopsy. Occasionally this weight was not available so that a blank is shown in this column.

Sample Weight

Weight in grams of the sample which was analyzed. Blanks in this column indicate the sample was not analyzed for this study. Sometimes the sample weight exceeded the whole organ weight. In general, this was a result of the tissue being fixed after the autopsy, so the tissue picked up fluid.

Tracer Yield

Percentage of the Pu 242 tracer which was recovered. A value of zero indicates that the sample was run but that no tracer was recovered. A value of blank indicates that the sample was not analyzed.

APHA Activity and MS Activity

Plutonium 239 and Pu 240 alpha activity in disintegrations per minute for the whole sample. If a sample was analyzed and these columns are blank, it indicates that the count of the sample did not differ significantly from the background count for the counting device used.

APHA Error, MS Error and Ratio Error

Coefficient of variation expressed in percent as determined by counting statistics. (For a single count, standard deviation = $\sqrt{n}$) This is not an estimate of the overall error, but only that based on the counting statistics. (See the data on Quality Assurance for evaluation of the overall errors in measurement.)

Pu 240/239 Ratio

Ratio of number of atoms of Pu 240 to the number of atoms of Pu 239, as determined by mass spectrometry.

Spike Type

Indicates the isotopes with which some of the tissue samples were spiked for quality assurance purposes. Spikes contained essentially only the Pu isotopes shown on the next page. (See discussion of Quality Assurance data below, together with Figures 2,3,4, and 5 and Tables 8 through 14 for Q.A. results.)

Spike Type	Isotopes of Plutonium
1	239
2	238
3	236
4	239 plus 238
5	239 plus 236
6	236 plus 238

Note that all the officially reported data on plutonium analyses from MCL are shown in Table 5, including measurements of tissues not utilized for the multiple regression analyses such as spiked tissues (used for quality assurance) and tissues from individuals possibly exposed to weapons grade plutonium (who might have resided on Western Slope, etc.).

MCL did not report the actual measurements of each sample together with the background, but only the measurements where the statistical analysis showed a significant difference from the background. The background level of the various machines used for counting varied from day to day and from machine to machine, and the length of time of counting also varied; thus the minimum detectable level was different for each sample measured. (See discussion of the problem of counts near background under Statistical Analysis Section 4.)

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
1-2	LIVER	1970	823.2	41	1.42	9.2					
1-3	LUNG		354.5	35	.45	20.0					
2-2	LIVER	1800	1025.7	51	3.50	5.6	4.36	2.3	.22	3.9	
2-3	LUNG	1400	1092.2	25			.54	4.7	.14	11.0	
3-2	LIVER	2070	609.5	28	.76	16.0	1.04	1.8	.23	3.0	
3-3	LUNG	620	624.3	49	.38	11.0	.41	7.9	.21	15.0	
4-2	LIVER	1640	777.0	12	.83	19.0	.96	1.7	.23	2.8	
4-3	LUNG	1000	811.9	48			.18	16.0	.27	24.0	
5-2	LIVER	1500	562.0	25			.51	5.2	.19	8.2	
5-3	LUNG	700	663.3	45			.20	4.5	.16	11.0	
6-2	LIVER	1700	795.0	31	1.55	9.7	1.45	1.2	.16	2.5	
6-3	LUNG	700	602.3	58			.35	5.7	.25	9.4	
7-2	LIVER	1700	633.2	56	2.65	6.7	3.15	.7	.18	1.3	
7-3	LUNG	1100	880.3	32	.61	21.0	.79	1.7	.09	5.4	
8-2	LIVER	2400	665.8	35	2.24	9.8	2.04	6.7	.32	11.0	
8-3	LUNG	910	1537.3	36	.57	25.0	.66	2.4	.13	7.0	
9-2	LIVER	1400	870.6	76	2.12	6.1	2.99	7.1	.28	11.0	
9-3	LUNG	500	646.1	41			.29	4.2	.10	12.0	
10-2	LIVER	1500	682.6	43	1.13	9.8	1.52	4.9	.25	8.2	
10-3	LUNG	900	1086.8	43			.28	2.5	.13	5.1	
11-2	LIVER	2100	648.8	33	1.33	10.0	1.57	1.9	.18	4.0	
11-3	LUNG	420	413.4	47	.22	26.0	.30	5.4	.16	12.0	
12-2	LIVER	2140	399.6	59	.30	22.0	.25	4.0	.21	7.2	
12-3	LUNG	400	329.0	55			.07	7.2	.17	17.0	
13-2	LIVER	1680	744.4	56	1.90	8.9	2.03	1.9	.18	4.0	
13-3	LUNG		322.0	50			.09	3.7	.13	9.0	
14-2	LIVER	1250	771.3	64	.73	11.0	.82	2.3	.21	4.6	
14-3	LUNG	500	784.8	52	.17	27.0	.19	6.0	.16	15.0	
15-2	LIVER	1000	643.3	61	1.82	13.0	1.98	16.0	.22	30.0	
15-3	LUNG	420	401.7	60			.14	4.6	.28	7.5	
16-2	LIVER	1200	781.9	53	1.51	13.0					
16-3	LUNG	350	452.2	41							
17-2	LIVER	1850	697.0	45	.64	27.0	1.22	6.5	.25	12.0	
17-3	LUNG	350	581.1	54			.05	2.7	.16	6.4	
18-2	LIVER	2200	814.7	48	3.08	12.0	2.67	3.1	.19	6.3	
18-3	LUNG	615	632.0	51			.21	2.6	.16	6.5	
19-2	LIVER	1280	830.3	68	1.81	12.0					
19-3	LUNG		672.4	44							
20-2	LIVER	1770	691.6	57			.36	2.6	.20	4.8	
20-3	LUNG		367.3	47			.64	3.7	.15	6.3	

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
21-2	LIVER	1500	686.2	47	1.36	8.6	1.37	2.3	.21	3.1	
21-3	LUNG	970	875.6	62							
22-2	LIVER	1420	1327.5	46	5.59	10.0	5.82	1.9	.21	4.1	
22-3	LUNG	1000	953.2	53	.57	22.0	.29	5.1	.18	10.0	
23-2	LIVER	1810	1709.6	34	3.68	13.0	3.69	1.4	.20	2.6	
23-3	LUNG	2080	1393.7	55			.19	6.7	.23	12.0	
24-2	LIVER	2350	1093.2	14			.52	21.0	.24	24.0	
24-3	LUNG	1450	1237.7	37	.66	9.9	1.01	4.9	.21	9.2	
25-2	LIVER	1900	807.2	23	1.11	14.0	1.45	4.7	.21	9.4	
25-3	LUNG	950	895.2	40	.19	25.0	.18	4.1	.18	8.3	
26-2	LIVER	1720	805.4	60	2.06	4.8	2.24	2.5	.21	3.8	
26-3	LUNG		445.1	60							
27-2	LIVER	1850	560.2	71	1.28	5.2	1.34	4.8	.19	11.0	
27-3	LUNG	910	817.7	55	.17	18.0					
28-2	LIVER	1850	737.1	29	.62	26.0	.94	7.7	.28	14.0	
28-3	LUNG	725	663.8	41							
29-2	LIVER	2860	985.4	39	.74	16.0	.56	5.7	.27	9.1	
29-3	LUNG	915	839.0	39							
30-2	LIVER	1400	719.4	56	.94	13.0	1.13	6.4	.26	4.2	
30-3	LUNG	780	623.7	53	.36	23.0					
31-2	LIVER	1200	810.6	43	5.40	7.5	5.81	.4	.16	.8	
31-3	LUNG	720	600.0	20			.42	6.6	.13	16.0	
32-2	LIVER	1500	860.6	0							
32-3	LUNG	700	671.7	47	.25	27.0	.25	8.9	.10	17.0	
33-2	LIVER	2000	735.2	48	.78	15.0	1.18	2.9	.19	5.6	
33-3	LUNG	800	749.4	50			.37	2.5	.10	7.4	
34-2	LIVER	2430	753.5	47	1.33	12.0	1.37	1.3	.22	2.3	
34-3	LUNG	435	445.1	32							
35-2	LIVER	1600	697.5	34	2.22	6.9	2.25	2.8	.20	5.4	
35-3	LUNG	1580	567.2	14	.66	26.0	.83	3.6	.13	7.6	
36-2	LIVER	1400	693.9	33	.67	13.0	.64	5.3	.23	8.1	
36-3	LUNG	700	619.8	52							
37-2	LIVER	900	861.5	45	1.46	6.9	1.39	1.8	.19	3.8	
37-3	LUNG		347.0	62							
38-2	LIVER	2400									
38-3	LUNG										
39-2	LIVER	1220	952.6	23	3.78	11.0	5.21	1.1	.19	2.2	
39-3	LUNG	1440	1199.9	23	.74	22.0	.76	2.3	.15	5.8	
40-2	LIVER	1380	752.5	46	1.08	13.0	.93	3.1	.20	5.8	
40-3	LUNG	800	365.0	26							

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
41-2	LIVER	2500	891.1	66	2.46	7.7	2.91	2.0	.18	4.3	
41-3	LUNG		473.4	41	.42	23.0	.43	3.9	.07	14.0	
42-2	LIVER	1200	745.5	59	.64	18.0	.70	2.1	.20	3.8	
42-3	LUNG	310	302.7	56			.07	6.1	.09	16.0	
43-2	LIVER	2000	639.6	40	.67	19.0	.76	4.8	.22	9.4	
43-3	LUNG	280	257.5	33			.20	12.0	.17	22.0	
44-2	LIVER	1640	664.4	10	.93	31.0	1.12	3.1	.18	6.7	
44-3	LUNG	750	309.7	37			.15	11.0	.24	20.0	
45-2	LIVER	1470	420.4	52	.47	15.0	.74	3.2	.17	6.3	
45-3	LUNG	590	554.1	32	.25	25.0	.17	6.5	.13	18.0	
46-2	LIVER	1400	501.8	57	2.72	7.3	2.60	1.3	.19	2.3	
46-3	LUNG	550	520.9	55	.27	19.0	.33	8.1	.27	15.0	
47-2	LIVER	1100	884.0	62	2.97	3.9	3.58	2.5	.26	3.7	
47-3	LUNG	650	615.2	43							
48-2	LIVER	1350	441.8	10							
48-3	LUNG	1000	230.3	51							
49-2	LIVER	940	770.2	66	2.96	5.4	2.94	1.3	.20	2.5	
49-3	LUNG	280	273.3	63	.19	22.0	.30	3.3	.14	8.6	
50-2	LIVER	1140	588.8	53	.96	15.0	1.12	1.8	.20	3.4	
50-3	LUNG	280	235.7	40			.22	5.6	.14	12.0	
51-2	LIVER	1050	716.8	23	1.47	20.0	1.81	9.5	.25	11.0	
51-3	LUNG	400	376.8	49			.05	12.0	.18	23.0	
52-2	LIVER	2300	782.8	88	.73	6.1	.99	4.9	.28	7.9	
52-3	LUNG	1000	1021.5	54			.08	6.4	.16	16.0	
53-2	LIVER	1500	680.1	11			.82	8.0	.21	8.5	
53-3	LUNG	130	982.2	76			.13	9.5	.17	17.0	
54-2	LIVER	1500	694.6	40	1.27	5.6	1.20	10.0	.21	5.0	
54-3	LUNG	800	1064.2	51	.26	12.0					
55-2	LIVER	1370	1217.4	68	1.56	9.1					
55-3	LUNG	520	385.2	61			.15	13.0	.22	21.0	
56-2	LIVER	2600	841.1	60	.79	11.0	1.09	5.4	.24	10.0	
56-3	LUNG	920	386.8	49							
57-2	LIVER	2140	717.1	61	1.46	7.0	1.49	4.0	.16	8.2	
57-3	LUNG	500	547.3	48							
58-2	LIVER	920	366.2	61	.87	12.0					
58-3	LUNG	330	98.2	18							
59-2	LIVER	1050	807.5	22	2.12	7.4	2.47	8.2	.18	7.0	
59-3	LUNG	450	448.2	60			.12	10.0	.23	17.0	
60-2	LIVER	1350	614.7	76	.85	9.6					
60-3	LUNG	350	322.5	53	.32	20.0					

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
61-2	LIVER	2400	695.2	86	1.45	10.0	1.66	1.1	.19	2.1	
61-3	LUNG	1300	1483.4	28			.18	6.9	.19	16.0	
62-2	LIVER	5000	791.3	73			.25	21.0	.28	28.0	
62-3	LUNG	500	898.4	27							
63-2	LIVER	1300	661.4	90	1.51	4.4	1.55	3.2	.19	6.8	
63-3	LUNG	950	1025.2	89							
64-2	LIVER	1620	800.4	52	3.61	4.5	4.99	5.7	.26	11.0	
64-3	LUNG	650	614.3	10	1.40	21.0					
65-2	LIVER	2900	930.6	59	1.03	8.4	1.11	1.9	.25	3.6	
65-3	LUNG	850	823.7	37			.11	7.6	.23	15.0	
66-2	LIVER	1250	692.8	47	1.90	7.1					
66-3	LUNG	1000	1032.0	11			.38	4.4	.19	8.6	
67-2	LIVER	1320	590.0	61	1.35	8.2	1.30	2.8	.16	5.9	
67-3	LUNG	290	297.2	0							
68-2	LIVER	1550	712.3	51	1.35	3.8	1.30	.9	.20	1.8	
68-3	LUNG	550	405.5	55	.32	7.3					
69-2	LIVER	1700	679.9	53	1.18	7.5	1.21	2.8	.18	5.7	
69-3	LUNG	700	667.5	33	.22	26.0					
70-2	LIVER	1650	1054.1	24	2.17	8.6	2.18	2.2	.21	3.7	
70-3	LUNG	560	489.7	46	.43	16.0					
71-2	LIVER	1220	815.9	18	3.00	11.0	2.97	2.2	.14	3.2	
71-3	LUNG	275	768.7	40	.52	15.0					
72-2	LIVER	2750	800.0	56	1.07	8.6	1.01	2.6	.18	5.7	
72-3	LUNG	1110	755.9	24			.23	10.0	.17	20.0	
73-2	LIVER	950	710.4	54	1.71	7.5	2.07	2.3	.22	4.6	
73-3	LUNG	700	617.3	0							
74-2	LIVER	2200	780.9	53	1.17	8.6	1.52	2.4	.22	3.8	
74-3	LUNG	420	816.3	16							
75-2	LIVER	1600	719.4	12	2.70	10.0	3.01	3.5	.22	6.3	
75-3	LUNG	1250	466.3	26							
76-2	LIVER	1670	479.7	14	1.11	21.0	1.26	4.4	.22	7.7	
76-3	LUNG	410	431.5	58							
77-2	LIVER	1400	730.2	56	1.37	7.7					
77-3	LUNG	480	530.6	0							
78-2	LIVER	1500	1260.3	11	1.17	22.0	1.03	3.2	.18	7.1	
78-3	LUNG	900	822.8	62	.24	20.0					
79-2	LIVER	2100	803.7	77	2.01	5.5	2.22	.9	.19	1.5	
79-3	LUNG	720	736.2	49			.12	10.0	.17	20.0	
80-2	LIVER	2300	523.8	15	1.70	13.0	1.86	7.3	.23	12.0	
80-3	LUNG	1715	1488.5	10	1.99	25.0					

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
81-2	LIVER	1910	694.2	38	1.33	7.1	1.75	3.6	.25	7.2	
81-3	LUNG		959.8	27							
82-2	LIVER	2885	1425.0	54	1.16	5.1	1.20	3.3	.15	8.2	
82-3	LUNG	1735	581.3	50	.40	17.0	.43	5.7	.06	9.2	
83-2	LIVER	1060	358.7	11	.75	23.0	.63	7.0	.20	16.0	
83-3	LUNG	350	340.9	8							
84-2	LIVER	1620	586.4	38	.46	19.0	.37	13.0	.18	20.0	
84-3	LUNG	1540	624.1	40			.07	12.0	.17	23.0	
85-2	LIVER	1700	1147.0	26			.31	4.4	.16	9.4	
85-3	LUNG	710	504.9	40							
86-2	LIVER	1300	625.2	57	.47	14.0					
86-3	LUNG	560	501.1	60							
87-2	LIVER	1550	699.5	37	.35	23.0	.62	6.1	.24	10.0	
87-3	LUNG	1040	950.5	26			.25	4.6	.14	9.5	
88-2	LIVER	2300	1140.4	26	2.04	7.1	2.02	1.8	.19	3.7	
88-3	LUNG	1220	1027.2	37			.37	8.4	.26	13.0	
89-2	LIVER	7200	1272.2	22	1.11	16.0					
89-3	LUNG	860	787.1	35	.19	26.0	.26	14.0	.20	25.0	
90-2	LIVER	2200	908.7	0							
90-3	LUNG	640	595.5	10			.17	16.0	.21	18.0	
91-2	LIVER	700	566.1	0							
91-3	LUNG	350	447.8	10							
92-2	LIVER	2250	832.3	59	1.18	5.8	1.00	6.1	.16	9.0	
92-3	LUNG	750	614.7	57			.16	2.6	.09	8.6	
93-2	LIVER	6142	671.7	74	.54	10.0	.53	4.0	.20	6.1	
93-3	LUNG	600	564.3	58							
94-2	LIVER	1680	788.4	56	1.13	8.4	1.32	1.4	.21	2.6	
94-3	LUNG	760	721.4	23			.25	4.4	.13	9.7	
95-2	LIVER	1360	1309.1	33	8.26	5.8	8.27	1.5	.17	2.4	
95-3	LUNG	710	631.3	29	.47	31.0	.68	4.0	.22	8.4	
96-2	LIVER	1800	841.0	53	.89	6.7			.22	16.0	
96-3	LUNG	600	761.3	64	.52	7.6					
97-2	LIVER	2800	800.1	50	.76	8.5	.72	13.0	.17	29.0	
97-3	LUNG	900	1046.4	52			.22	7.8	.19	15.0	
98-2	LIVER	1460	668.8	62	1.23	6.9	.59	9.3	.23	12.0	
98-3	LUNG	410	296.4	53							
99-2	LIVER	4860	1202.9	61	.19	23.0	.21	7.5	.14	16.0	
99-3	LUNG	710	531.5	62			.06	9.8	.14	20.0	
100-2	LIVER	1830	1369.6	61	2.73	5.2	2.75	1.1	.17	2.2	
100-3	LUNG	1160	945.8	49			.09	8.7	.27	16.0	

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
101-2	LIVER	1540	590.5	66	.45	12.0	.51	1.6	.20	3.4	
101-3	LUNG	300	489.7	16							
102-2	LIVER	800	620.0	31	.41	14.0	.45	5.2	.30	7.9	
102-3	LUNG	520	488.9	24			.15	11.0	.16	22.0	
103-2	LIVER	1740	671.9	62	.71	21.0	.89	2.5	.22	3.8	
103-3	LUNG	550	510.4	59	.13	24.0					
104-2	LIVER	1900	529.7	50	.60	9.8	.67	3.6	.19	6.2	
104-3	LUNG	1025	951.8	39	.79	9.2	.38	7.4	.17	16.0	
105-2	LIVER	1250	1070.4	44	1.61	8.0					
105-3	LUNG	980	869.3	57			.21	3.5	.16	7.6	
106-2	LIVER	1300	508.6	61	1.24	4.9					3
106-3	LUNG	800	446.4	38	.16	30.0	.15	4.9	.13	11.0	3
107-2	LIVER	1290									
108-2	LIVER	1460	731.9	42	2.23	8.0					
108-3	LUNG	480	383.0	59							
108-8	LUNG	510	338.3	61			.05	7.3	.15	19.0	3
109-2	LIVER	2400	660.8	46	.30	34.0	.32	14.0	.18	25.0	
109-3	LUNG	600	760.3	31							
110-2	LIVER	1480	656.9	49	1.25	14.0	.89	7.3	.19	14.0	
110-3	LUNG	680	627.5	56			.09	11.0	.20	26.0	
111-2	LIVER	2180	290.3	26							
111-3	LUNG	470	388.0	68							
111-7	LIVER	2180	239.7	60	3.74	6.4	4.06	.3	.04	.8	1
112-2	LIVER	1250	634.8	61	.98	6.2	.95	1.7	.18	3.6	6
112-3	LUNG	700	606.1	59	.47	9.3	.11	5.6	.06	21.0	6
113-2	LIVER	2100	986.0	24			.29	12.0	.17	26.0	
113-3	LUNG	900	951.5	24			.23	5.3	.17	11.0	
114-2	LIVER	2470	756.8	56	1.12	8.4					
114-3	LUNG	1200	1109.7	16	.19	36.0					
115-2	LIVER	1200	648.2	59	1.74	6.5	1.87	3.3	.21	7.2	
115-3	LUNG	880	1015.2	27			.26	14.0	.16	30.0	
116-2	LIVER	1200	575.8	63	2.28	4.2	2.31	4.3	.17	7.2	3
116-3	LUNG	450	896.1	58	.46	8.2	.43	2.1	.11	5.4	3
117-2	LIVER	1660	518.9	12	1.89	22.0	2.48	3.5	.18	3.9	
117-3	LUNG		627.9	41							2
117-7	LIVER	1660	377.8	65	2.44	7.1	2.57	2.2	.07	7.3	1
117-8	LUNG		178.0	17	2.38	5.8	2.56	1.7	.05	9.3	4
118-2	LIVER	720	685.8	58	3.90	4.9	4.28	4.6	.17	9.3	
118-3	LUNG	490	447.1	28	.32	26.0					
118-8	LUNG	570	423.9	63	4.87	2.9	4.65	.6	.01	4.4	5

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
119-2	LIVER	1300	860.9	10			1.11	13.0	.19	16.0	
119-3	LUNG	500	390.9	31							
119-8	LUNG	400	285.3	20	4.57	10.0	5.25	1.7	.03	13.0	5
120-2	LIVER	1420	756.9	24	1.71	14.0	1.68	6.1	.23	8.2	
120-8	LUNG	500	410.2	38			.17	3.7	.15	8.4	2
121-2	LIVER	1800	944.3	55	5.83	5.3	5.93	.9	.10	2.3	
121-3	LUNG	900	250.0	34	.29	29.0					6
121-8	LUNG	900	465.2	42	1.19	7.0					6
122-2	LIVER	1420	952.8	33							
122-3	LUNG	640	626.9	56							
123-2	LIVER	1090	520.1	32	1.84	15.0	1.32	1.9	.16	4.4	
123-3	LUNG	480	494.8	0							
124-2	LIVER	2150	676.6	49	1.28	9.8	1.50	2.5	.18	4.5	
124-3	LUNG	1050	932.0	49	.17	28.0					
125-2	LIVER	1700	894.1	58	2.09	12.0	2.22	2.9	.20	4.2	
125-3	LUNG	420	373.8	48							
125-8	LUNG	420	440.4	46	.23	21.0					6
126-2	LIVER	3900	657.1	15	1.83	24.0					
126-3	LUNG	530	472.7	24			.26	5.7	.05	20.0	
127-2	LIVER	1630	875.4	22	2.87	9.0	1.29	4.4	.18	8.9	
127-3	LUNG		775.3	37							
128-2	LIVER	1350									
128-3	LUNG										
129-2	LIVER	1050	763.5	19							
129-3	LUNG	280	250.6	17							
130-2	LIVER	1030	1029.2	19	3.85	8.7	4.94	8.9	.23	17.0	
130-3	LUNG	650	624.6	45	.34	22.0	.50	7.6	.13	19.0	
130-8	LUNG	580	334.7	49	.32	15.0	.31	4.3	.13	11.0	6
131-2	LIVER	2150	904.1	0							
131-3	LUNG	800	997.0	34							
132-2	LIVER	1230	510.5	32							1
132-3	LUNG	670	687.5	15			.42	4.6	.09	12.0	
132-7	LIVER	1230	588.3	53	.44	17.0					
132-8	LUNG	700	705.5	17	.63	23.0	.57	6.3	.14	7.1	
133-2	LIVER	1050	449.7	13	5.68	11.0					
133-3	LUNG	450									
134-2	LIVER	1290	685.1	29	1.86	9.0	1.89	2.9	.20	5.6	
134-3	LUNG	260	234.4	37			.33	16.0	.18	7.9	
135-2	LIVER	1400	681.6	25	1.95	10.0	1.98	6.4	.20	12.0	
135-3	LUNG	600	735.0	33	.44	23.0	.31	4.1	.11	11.0	

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
136-2	LIVER	1300	707.9	49	1.92	9.0	2.28	2.4	.20	3.4	
136-3	LUNG	500	483.4	64	.71	9.2	.05	10.0	.17	21.0	
137-2	LIVER	1290	901.5	51	1.77	7.1	1.70	2.4	.21	4.6	
137-3	LUNG	930	793.7	46			.28	5.4	.11	15.0	
138-2	LIVER	2120	902.2	0							
138-3	LUNG										
138-8	LUNG		907.5	30	2.22	9.1					4
139-2	LIVER	1550	794.5	33	1.67	8.8	1.51	2.1	.18	4.1	
139-3	LUNG	750	622.7	33			.29	7.9	.17	10.0	
140-2	LIVER	1440	916.6	31			.14	6.5	.23	10.0	
140-3	LUNG	410	377.7	40							
141-2	LIVER	1560	646.9	12	1.33	21.0	1.05	5.0	.19	10.0	
141-3	LUNG	500	— 733.9	12							
142-2	LIVER	2100	833.3	48	.53	18.0	.56	3.8	.20	7.0	
142-3	LUNG	380	— 565.1	29							
143-2	LIVER	1500	606.0	56	.73	8.0	.94	6.3	.22	13.0	
143-7	LIVER	1500	452.9	52	.31	22.0					
143-8	LUNG	310	263.9	76	.22	15.0					6
144-2	LIVER	850	813.4	31	1.37	15.0	1.40	1.6	.18	2.6	
144-3	LUNG	360	332.5	35			.19	9.9	.21	19.0	
145-2	LIVER	1250	726.8	24	1.66	19.0					
145-3	LUNG	500	528.4	62							6
145-8	LUNG	500	494.4	25							
146-2	LIVER	1880	761.1	0							
146-3	LUNG	430	409.8	50							
146-8	LUNG	920	801.2	19							6
147-2	LIVER	3000	680.7	27	.63	24.0	.88	11.0	.19	21.0	
147-3	LUNG	900	756.8	37							
148-2	LIVER	1270	732.3	53	1.29	6.0	.72	3.2	.16	4.4	
148-3	LUNG	470	453.2	49	.15	24.0	.20	5.2	.09	16.0	
149-2	LIVER	2150	1216.3	12	1.35	15.0					
149-3	LUNG	610	558.0	41							
150-2	LIVER	1400	644.2	65	1.04	5.4	1.17	1.5	.20	3.0	
150-3	LUNG	500	489.0	57	.17	22.0	.13	2.3	.12	5.8	
150-7	LIVER	1400	650.0	52	1.00	7.6	1.08	10.0	.18	20.0	
150-8	LUNG	700	585.9	19							
151-2	LIVER	1040	1016.2	53	2.63	8.0	2.56	.5	.16	1.1	
151-3	LUNG	310	— 501.5	70	.23	16.0					6
151-8	LUNG	390	— 754.8	60	.22	12.0	.24	3.1	.09	8.3	
152-2	LIVER	1860	789.3	72	.90	6.8	1.00	2.0	.17	4.2	

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
152-3	LUNG	1040	695.9	59			.11	11.0	.18	21.0	6
152-8	LUNG	1030	806.5	59							
153-2	LIVER	2300	920.7	52	1.03	7.5					
153-3	LUNG	800	925.0	8							
154-2	LIVER	880	684.9	26	2.27	7.5	2.23	1.6	.17	3.1	
154-3	LUNG	500	727.7	61							
155-2	LIVER	1700	1073.6	53	3.41	4.4	3.44	5.1	.17	10.0	
155-3	LUNG	520	522.8	77	.16	16.0					
156-2	LIVER	2120	1056.3	47	1.60	6.5	1.59	2.5	.17	4.7	
156-3	LUNG	700	687.1	23							
156-8	LUNG	850	782.8	47							
157-2	LIVER	2300	640.0	64	.83	7.2	.75	5.2	.15	11.0	
157-3	LUNG	1280	972.2	30	.64	17.0	.59	5.3	.15	12.0	
158-2	LIVER	1660	681.4	58	4.55	3.8	4.23	.6	.16	.8	
158-3	LUNG	625	603.2	65	.29	14.0					
159-2	LIVER	1200	721.5	16			.31	12.0	.22	23.0	
159-3	LUNG	1110	1129.9	11							
160-2	LIVER	2110	730.0	84							
160-3	LUNG	700	931.5	67	.15	21.0					
161-2	LIVER	1320	768.2	24	5.11	6.2	5.00	2.3	.17	4.5	
161-3	LUNG	680	560.1	69	.36	11.0					
162-2	LIVER	1250	684.4	54	1.70	5.8					
162-3	LUNG	970	668.1	65	.12	25.0	.14	11.0	.13	27.0	
163-2	LIVER	1410	847.5	28	2.67	6.6	3.18	2.1	.19	4.5	
163-3	LUNG	270	231.0	52	2.82	4.8	2.67	2.2	.18	3.7	
164-2	LIVER	1850	608.4	81							
164-3	LUNG	850	782.6	24			.22	6.8	.13	16.0	
165-2	LIVER	1360	672.3	25			.25	9.4	.14	12.0	
165-3	LUNG	830	712.6	60			.09	3.7	.12	8.9	
166-2	LIVER	1370	859.3	13	2.24	13.0	2.70	5.8	.19	9.9	
166-3	LUNG	440	389.3	32	1.00	16.0					
166-8	LUNG	630	581.4	29	.62	20.0	.65	3.0	.20	5.9	
167-2	LIVER	1050	605.0	55	1.22	6.6	1.12	1.3	.19	2.3	
167-3	LUNG	370	362.5	62							
168-2	LIVER	1300	655.4	40	2.69	7.9	2.80	1.2	.18	2.5	
168-3	LUNG	1200	1165.0	63	.45	9.7	.49	1.9	.08	6.7	
169-2	LIVER	2600	664.1	51	.74	8.8	.85	2.3	.22	4.6	
169-3	LUNG	600	882.1	45			.20	2.7	.10	7.4	
170-2	LIVER	1060	444.2	62	1.01	9.6	1.25	1.1	.19	2.2	
170-3	LUNG		615.3	67	.33	9.6	.31	2.0	.11	4.8	

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
171-2	LIVER	1850	547.2	38	.20	23.0					
171-3	LUNG	400	754.7	41							
172-2	LIVER	1200	731.7	36	2.22	9.9	2.28	1.0	.19	1.9	
172-3	LUNG	550	469.3	19			.28	3.4	.15	7.7	
173-2	LIVER	2740	686.0	63			.09	12.0	.25	23.0	
173-3	LUNG	640	498.4	54	.23	25.0	.68	7.1	.18	17.0	
174-2	LIVER	1470	754.8	47	.90	14.0	1.08	7.9	.19	9.7	
174-3	LUNG	770	711.3	38			.58	7.5	.16	16.0	
174-8	LUNG	690	638.9	39							
175-2	LIVER	1300									
175-3	LUNG										
176-2	LIVER	1500	706.1	67	.45	13.0	.50	2.1	.21	4.1	
176-3	LUNG	670	706.5	32	.76	19.0	.69	3.9	.13	11.0	
176-7	SAMPLE RETURNED NOT ANALYZED										
176-8	LUNG	820	589.1	69	.44	8.1	.51	2.0	.09	6.1	
177-2	LIVER	1440	719.9	41	1.29	11.0	1.28	2.0	.20	3.0	
177-3	LUNG	610	579.7	31							
178-2	LIVER	2100	721.9	55	.42	16.0	.49	1.4	.23	2.1	
178-3	LUNG	880	1054.5	67	.23	19.0	.24	4.6	.13	11.0	
178-7	LIVER	2100	561.8	26	1.75	12.0	1.77	2.9	.09	11.0	1
179-2	LIVER	1040	684.0	20	1.94	14.0	1.92	.6	.18	1.0	
179-3	LUNG	620	562.9	74	.11	20.0	.15	12.0	.19	24.0	
180-2	LIVER	1500	901.9	42	2.66	4.1	2.63	1.3	.19	2.5	
180-3	LUNG	525	506.7	70	.39	7.7	.34	2.5	.11	7.6	
181-2	LIVER	2100	807.9	51	.84	13.0					
181-3	LUNG	800	1021.4	43			.19	2.9	.09	9.2	
182-2	LIVER	1100	652.7	47	1.43	11.0	1.77	.6	.18	1.2	
182-3	LUNG	560	472.8	21			.20	5.0	.22	7.5	
183-2	LIVER	2100	673.8	39	1.47	12.0					
183-3	LUNG	1270	852.9	8							
184-2	LIVER	1650	763.8	8							
184-3	LUNG	900	802.0	30							
185-2	LIVER	1260	853.6	25	2.97	8.0					
185-3	LUNG	390	353.8	43							
185-8	LUNG	570	433.3	23	2.38	12.0	2.61	2.4	.19	4.0	
186-2	LIVER	1320	711.6	68	2.77	2.3	2.93	1.8	.23	3.5	
186-3	LUNG	235	313.7	65	.12	26.0	.16	4.8	.13	12.0	
187-2	LIVER	1240	531.3	58	.82	13.0	.95	2.0	.17	4.7	
187-3	LUNG	530	498.7	53	.22	21.0	.26	8.0	.15	11.0	
187-7	LIVER	1240	569.0	40	1.40	11.0	1.18	1.4	.20	2.8	

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
187-6	LUNG	660	630.5	56	.20	22.0	.25	2.9	.13	7.0	
188-2	LIVER	1250	673.5	15			1.11	1.0	.18	2.0	
188-3	LUNG	220	210.1	58			.09	4.0	.11	12.0	
188-8	LUNG	280	267.0	61			.11	7.8	.12	18.0	
189-2	LIVER	1425	824.6	59	3.07	5.8	3.28	.7	.19	1.2	
189-3	LUNG	650	953.4	64	.19	29.0	.21	3.3	.19	7.3	
190-2	LIVER	1500	879.5	42	3.85	7.1	3.62	2.1	.18	4.2	
190-3	LUNG	1000	1378.3	9			.26	2.6	.10	8.6	
190-7	LIVER	1500	623.9	53	2.54	7.3	2.48	.6	.17	1.2	
190-8	LUNG	1100	965.5	81			.18	3.5	.11	9.0	
191-2	LIVER	1300	697.0	43	1.65	11.0	1.61	.7	.17	1.4	
191-3	LUNG	520	523.2	44			.16	6.9	.17	14.0	
191-7	LIVER	1300	569.5	26	1.53	14.0	1.66	1.1	.21	2.0	
191-8	LUNG	450	357.9	18							
192-2	LIVER	900	621.6	39							
192-3	LUNG	800	987.5	11			.20	4.1	.11	11.0	
193-2	LIVER	1000	695.4	27	1.57	21.0					
193-3	LUNG	960	1023.2	11							
194-2	LIVER	1720	613.2	39	2.23	8.4	2.45	5.3	.18	6.6	
194-3	LUNG	760	635.0	51	.23	18.0					
195-2	LIVER	1100	469.5	59	1.31	7.5					
195-3	LUNG	550	480.5	26			.12	8.0	.17	13.0	
196-2	LIVER	1250	591.9	78	1.03	6.8					
196-3	LUNG	420	389.1	17			.34	7.0	.19	13.0	
197-2	LIVER	1500	827.0	65	.50	11.0	.54	9.6	.20	11.0	
197-3	LUNG	530	382.9	15	.52	23.0					
198-2	LIVER	1720	958.7	25	1.95	21.0	2.46	4.9	.19	10.0	
198-3	LUNG		655.4	66							
199-2	LIVER	1400	481.9	58	.39	14.0					
199-3	LUNG	420	446.4	63			.06	9.2	.16	21.0	
199-7	LIVER	1400	519.1	52	.87	7.8	.83	4.9	.19	11.0	
199-8	LUNG	640	694.4	70							
200-2	LIVER	1780	437.9	52	.64	14.0					
200-3	LUNG	560	570.0	52							
200-7	LIVER	1780	541.7	18	12.00	8.2	11.70	.8	.02	3.8	4
200-8	LUNG	780	545.3	81			.13	4.0	.13	9.2	
201-2	LIVER	900	885.9	70	2.00	5.7	2.19	1.4	.19	2.5	
201-3	LUNG	440	324.2	78							
201-8	LUNG	380	394.7	79							
202-2	LIVER	2500	845.4	62							

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
202-3	LUNG	730	455.1	44			.12	8.5	.08	21.0	
202-7	LIVER	2500	823.9	30							
202-8	LUNG	840	816.0	78							
203-2	LIVER	1600	672.5	36	.58	18.0					
203-3	LUNG	810	809.9	20							
203-7	LIVER	1600	623.1	41	.60	13.0					
203-8	LUNG	900	742.9	32							
204-2	LIVER	720	675.5	42	.69	9.0					
204-3	LUNG	340	221.0	17							
204-8	LUNG	450	353.0	40							
205-2	LIVER	800	784.1	52	2.25	7.9	2.33	1.2	.20	2.2	
205-3	LUNG	450	316.8	53							
205-8	LUNG	560	451.6	75	.12	22.0	.23	6.4	.15	13.0	
206-2	LIVER	1320	1046.1	87	1.72	3.8	2.05	2.5	.19	5.5	
206-8	LUNG	600	525.8	30							
207-2	LIVER	940	858.0	16	1.11	21.0					
207-3	LUNG	580	549.1	16			.33	14.0	.15	30.0	
208-2	LIVER	4200	677.0	49	.20	17.0					
208-3	LUNG	760	651.8	40			.11	3.2	.13	8.3	
209-2	LIVER	950	867.8	52	.45	22.0	.47	2.8	.18	5.2	
209-3	LUNG	490	529.8	52			.23	4.6	.10	13.0	
210-2	LIVER	2170	512.8	71			.07	9.0	.22	17.0	
210-3	LUNG	820	772.4	70							
210-7	SAMPLE RETURNED NOT ANALYZED										
210-8	LUNG	860	907.0	74			.08	5.5	.18	13.0	
211-2	LIVER	1110	516.7	66	.71	6.9	.87	8.1	.20	15.0	
211-3	LUNG	550	463.8	55			.21	18.0	.17	27.0	
211-7	SAMPLE RETURNED NOT ANALYZED										
211-8	LUNG	440	407.1	69							
212-2	LIVER	1400	662.4	60	2.57	5.8					
212-3	LUNG	520	338.0	53							
212-7	LIVER	1400	604.3	36	5.50	5.0	5.79	1.8	.06	5.7	5
213-2	LIVER	1150	748.0	52							
213-3	LUNG	510	451.5	36							
214-2	LIVER	1150	473.8	34	.59	23.0	.81	2.4	.21	4.6	
214-3	LUNG	560	539.4	48			.74	2.3	.22	4.0	
214-7	SAMPLE RETURNED NOT ANALYZED										
214-8	LUNG	1160	1075.0	70			.36	2.2	.11	6.0	
215-2	LIVER	2670	689.0	45	.60	16.0	.31	3.5	.19	6.4	
215-3	LUNG	940	937.3	34							

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
216-2	LIVER	1860	752.7	61	2.00	5.6					
216-3	LUNG	1760	1706.8	39							
217-2	LIVER	1580	488.9	61	.83	9.2	.86	3.0	.21	4.6	
217-3	LUNG	520	515.2	56							
218-2	LIVER	1100	501.3	44	.47	24.0	.25	6.2	.20	13.0	
218-3	LUNG	450	433.8	54			.28	4.5	.24	7.8	
219-2	LIVER	1720	710.2	22	1.93	13.0	2.00	2.4	.23	4.6	
219-3	LUNG	600	494.3	30			.27	11.0	.18	20.0	
219-7	SAMPLE RETURNED NOT ANALYZED										
219-8	LUNG		356.8	40			.22	4.9	.11	14.0	
220-2	LIVER	1150	625.8	31	2.73	9.3	3.00	2.7	.25	4.7	
220-3	LUNG	830	792.9	46							
221-2	LIVER	1325	838.7	39	3.88	7.3	3.57	1.1	.18	1.4	
221-3	LUNG	480	491.7	14							
222-2	LIVER	1100	831.5	29	1.85	11.0					
222-3	LUNG	450	397.9	0							
223-2	LIVER	1500	670.8	27	1.92	11.0					
223-3	LUNG	1200	886.0	27	.42	29.0					
224-2	LIVER	1000	660.5	34	2.21	9.3	2.29	1.7	.18	3.4	
224-3	LUNG	900	807.8	32							
225-2	LIVER	1870	703.5	70	1.75	5.1	1.85	1.1	.17	2.1	
225-3	LUNG	1250	800.3	77	.23	16.0	.24	2.1	.17	3.7	
225-7	LIVER	1[illegible]70	818.3	33	2.35	9.1	2.24	1.0	.18	1.9	
225-8	SAMPLE RETURNED NOT ANALYZED										
226-2	LIVER	1300	711.9	49	2.47	7.2	2.60	5.0	.18	8.8	
226-3	LUNG	690	785.6	54	.23	22.0					
227-2	LIVER	2430	462.4	46	.47	12.0	.51	2.8	.21	5.2	
227-3	LUNG	950	820.4	75	.56	6.4	.55	3.2	.16	6.4	
228-2	LIVER	1190	743.1	80	1.90	3.7	1.96	2.1	.18	4.2	
228-3	LUNG	450	406.0	42			.16	11.0	.14	8.1	
228-8	LUNG	430	386.8	62			.06	5.5	.20	10.0	
229-2	LIVER	1550	390.0	48	.96	11.0	1.02	1.7	.17	3.6	6
229-3	LUNG	550	511.9	37			.21	13.0	.20	24.0	
229-7	LIVER	1550	629.1	40	1.37	9.0	1.45	4.7	.21	8.5	
230-2	LIVER	2400	817.1	60	.37	9.7					
230-3	LUNG	1660	1378.0	36							
231-2	LIVER	1500	414.1	51	.62	11.0	.76	4.1	.22	8.9	
231-3	LUNG	370	302.0	61	.11	28.0					
231-8	LUNG	460	414.0	55							
232-2	LIVER	2975	909.4	48							

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
232-3	LUNG	1070	1119.8	63							
233-2	LIVER	2120	766.7	44	2.29	4.6	3.39	2.4	.19	4.5	
233-3	LUNG	1430	972.6	25	.38	27.0	.43	5.6	.13	11.0	
233-8	LUNG	1370	774.9	25	.30	24.0					
234-2	LIVER	1100	522.3	43	1.35	5.7	1.59	1.5	.20	3.0	
234-3	LUNG	600	560.3	40			.34	8.2	.20	16.0	
234-7	LIVER	1100	535.9	42	1.22	8.9					
234-8	LUNG	530	490.4	52			.15	19.0	.21	22.0	
235-2	LIVER	1500	610.1	35							
235-3	LUNG	450	365.2	58							
236-2	LIVER	5460	960.5	45	.60	14.0	.83	2.3	.23	4.3	
236-3	LUNG	690	489.0	57	.16	17.0	.14	3.9	.18	8.9	
236-8	LUNG	940	810.8	57	.23	20.0	.20	4.4	.15	11.0	
237-2	LIVER	1650	926.6	46	2.29	4.6	2.71	6.7	.20	13.0	
237-3	LUNG	790	710.9	38	.39	15.0	.55	12.0	.18	27.0	
238-2	LIVER	1820	851.9	45	4.03	5.6					
238-3	LUNG	800	744.7	59	.20	22.0	.23	7.8	.16	18.0	
239-2	LIVER	1700	935.1	33							
239-3	LUNG	870	686.7	56							
239-8	LUNG	740	808.4	58	.09	26.0	.10	7.4	.23	12.0	
240-2	LIVER	1550	702.4	31	2.58	4.4	2.59	1.6	.21	2.8	
240-3	LUNG	440	533.8	57							
240-7	SAMPLE RETURNED NOT ANALYZED										
241-2	LIVER	1150	462.5	61	.25	23.0	.29	6.3	.25	11.0	
241-3	LUNG	600	588.8	63	.38	12.0	.35	9.6	.08	15.0	
241-7	SAMPLE RETURNED NOT ANALYZED										
242-2	LIVER	1900	670.9	31	1.19	13.0					
242-3	LUNG	810	1093.5	14	.56	24.0					
243-2	LIVER	2200	705.5	39	2.39	8.7	2.15	1.8	.20	3.4	
243-3	LUNG	900	1081.1	25							
244-2	LIVER	1770	559.9	68	.97	5.6	.97	1.3	.18	2.7	6
244-3	LUNG	710	530.1	54							
244-7	LIVER	1700	754.3	57	1.18	5.5	1.53	2.4	.26	4.0	
244-8	LUNG	470	460.8	59			.39	6.6	.23	10.0	
245-2	LIVER	1970	866.7	35	1.02	13.0	1.44	2.7	.22	5.1	
245-3	LUNG	780	653.4	52	.11	30.0	.10	5.4	.15	13.0	
246-2	LIVER	2380	729.7	20							
246-3	LUNG	870	706.8	68	.19	24.0	.23	4.6	.20	8.8	
247-2	LIVER	1880	675.4	20	1.28	16.0					
247-3	LUNG	900	663.3	28							

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
247-7	LIVER	1880	505.6	41	1.19	9.8					6
248-2	LIVER	1130	518.5	27							
248-3	LUNG	550	521.5	50			.34	7.9	.17	19.0	
248-7	SAMPLE RETURNED NOT ANALYZED										
248-8	LUNG	630	598.3	53			.17	4.3	.11	13.0	
249-2	LIVER	900	723.8	17	2.02	7.1					
249-3	LUNG	350	348.7	17			.60	5.5	.23	7.7	
250-2	LIVER	2000	615.2	27	2.16	9.5	2.39	3.2	.21	6,9	
250-3	LUNG	700	— 1183.1	7			.46	2,6	.10	8.1	
251-2	LIVER	1920	1047.1	22	.90	20.0	1.21	.9	.20	1.6	
251-3	LUNG	650	542.9	26			.08	8.7	.18	20.0	
252-2	LIVER	2550	968.6	40	1.81	9.5	2.09	.8	.18	1.4	
252-3	LUNG	450	401.2	19			.22	7.3	.14	17.0	
253-2	LIVER	2100	536.1	33			.31	3.6	.20	7.3	
253-3	LUNG	970	836.8	41			.14	8.9	.15	20.0	
253-7	LIVER	2100	616.0	16			.23	8.0	.22	15.0	
254-2	LIVER	1730	671.3	47	.57	13.0	.67	6.3	.23	11.0	
254-3	LUNG	290	292.3	37							
254-7	LIVER	1730	607.4	27							
255-2	LIVER	980	840.3	52	5.04	6.0	5,24	.5	.20	.7	
255-3	LUNG	650	622.3	35			.13	1.7	.11	4.3	
256-2	LIVER	1400	512.6	19			.14	7.0	.21	11.0	
256-3	LUNG	500	294.4	53	.23	24.0	.31	5.0	.14	12.0	
257-2	LIVER	980	578.7	55	1.57	7.4					
257-3	LUNG	750	668.8	41							
258-2	LIVER	1600	759.0	68	1.67	4.3	1.81	1.9	.23	3.5	
258-3	LUNG	620	555.6	14							
258-7	LIVER	1600	413.9	47	.82	7.7					
259-2	LIVER	2300	911.9	52	1.31	5.1					
259-3	LUNG										
259-7	LIVER	2300	534.6	35	.88	8.6	.89	6.5	.20	7.7	
260-2	LIVER	1070	577.0	51	1.50	7.6	1.52	1.2	.20	2.4	
260-3	LUNG	590	425.1	53	.34	11.0	.37	4.6	.17	11.0	
261-2	LIVER	1980	902.3	67	2.15	2.9	2.12	4.9	.17	6.2	
261-3	LUNG	460	483.4	33			.59	5.6	.20	11.0	
262-2	LIVER	1240	785.7	36	2.25	12.0					
262-3	LUNG	600	607.2	59							
263-2	LIVER	2000	700.1	55	1.00	15.0	.77	2.4	.21	4.2	
263-3	LUNG	290	— 371.4	27							
264-2	LIVER	1240	625.3	27			,37	5.0	.21	5.5	

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
264-3	LUNG	480	456.5	47	.29	23.0					
265-2	LIVER	1000	556.3	39	1.29	11.0	1.44	2.7	.18	3.0	
265-3	LUNG	700	371.2	32			.08	4.6	.17	10.0	
266-2	LIVER	870	692.1	20							
266-3	LUNG	625	— 895.6	32							
267-2	LIVER	940	678.6	55	.78	4.4	.93	6.3	.18	7.0	
267-3	LUNG	850	— 1058.1	20			.34	3.2	.16	8.1	
268-2	LIVER	2100	1317.4	71	2.14	7.6	2.39	1.4	.19	1.9	
268-3	LUNG	740	719.1	61	.34	20.0	.32	1.5	.09	4,4	
269-2	LIVER	1870	1100.5	25	.64	22.0					
269-3	LUNG	680	— 1318.6	57							
270-2	LIVER	2240	1133.2	41	1.42	6.4	1.63	1.9	.19	3.3	
270-3	LUNG	900	— 1352.9	44	.33	21.0					
271-2	LIVER	2100	1071.6	52	1.39	7.6	1.72	4.6	.21	8.8	
271-3	LUNG										
272-2	LIVER	1660	1179.8	33	1.30	18.0	1.34	.8	.18	1.8	
272-3	LUNG	940	915.9	38			.10	8.9	.26	16.0	
273-2	LIVER	1050	801.4	25							
273-3	LUNG	440	420.4	47							
274-2	LIVER	1490	1098.2	31	1.83	11.0					
274-3	LUNG	400	— 919.8	50			.20	5.5	.19	13.0	
275-2	LIVER	1450	791.8	48	.88	9.7	.92	3.4	.20	7.7	
275-3	LUNG	600	503.3	34			.65	8.1	.19	12.0	
276-2	LIVER	1750	542.7	45	.26	18.0					
276-3	LUNG	960	818.3	33							
276-7	LIVER	1750	579.5	27							
276-8	LUNG	730	678.2	62							
277-2	LIVER	1100	1038.3	32	1.71	15.0	1.98	.9	.19	1.7	
277-3	LUNG	810	792.5	44			.12	16.0	.15	20.0	
277-8	LUNG	650	639.0	27							
278-2	LIVER	1420	1087.8	35	1.04	23.0					
278-3	LUNG	320	— 963.2	39							
279-2	LIVER	545	432.9	38							
279-3	LUNG	220	242.4	51							
279-8	LUNG	230	208.1	51							
280-2	LIVER	2150	873.5	55	.25	22.0					
280-3	LUNG	490	— 888.7	77							
280-7	LIVER	2150	694.6	82							
281-2	LIVER	2200	778.1	50	1.32	7.7					
281-3	LUNG	500	— 678.0	57			.19	3.9	.13	8.7	

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
281-7	LIVER	2200	918.7	27	1.17	9.0	1.29	3.0	.22	6.3	
282-2	LIVER	1740	846.2	28							
282-3	LUNG	1160	983.4	32							
282-7	LIVER	1740	760.6	25							
282-8	LUNG	1070	1146.2	15							
283-2	LIVER	3690	945.2	25	.90	11.0					
283-3	LUNG	570	533.9	21							
283-8	LUNG	560	518.3	18							
284-2	LIVER	1710	1046.7	35	2.44	5.4					
284-3	LUNG	590	499.2	63	.39	14.0					
284-8	LUNG	560	483.1	58			.14	5.6	.16	13.0	
285-2	LIVER	1820	1142.7	17	2.09	14.0					
285-3	LUNG	410	— 874.9	40							
286-2	LIVER	3350	600.6	69	.66	7.6					
286-3	LUNG	460	428.4	52			.22	6.7	.19	12.0	
287-2	LIVER	1310	946.7	75	.13	23.0	.18	5.7	.14	14.0	
287-3	LUNG	900	501.2	58							
288-2	LIVER	2230	668.9	51	.30	15.0	.80	4.1	.15	8.6	
288-3	LUNG	980	889.0	56							
289-2	LIVER	1000	994.6	15	3.53	10.0	3.38	1.9	.17	3.5	
289-3	LUNG	660	583.0	47	.19	25.0	.27	5.3	.14	15.0	
290-2	LIVER	2400	886.4	16			.73	4.8	.20	8.7	
290-3	LUNG	670	606.3	65							
290-7	SAMPLE RETURNED NOT ANALYZED										
291-2	LIVER	950	542.6	47	1.71	8.3	1.73	1.1	.17	2.2	
291-3	LUNG	570	530.7	38	.22	24.0					
292-2	LIVER	2750	676.0	24							
292-3	LUNG	700	613.9	35	.28	25.0	.19	2.8	.13	7.0	
293-2	LIVER	2700	806.1	53	1.56	9.2	1.46	3.0	.19	5.2	
293-3	LUNG	685	595.5	50			.22	13.0	.20	22.0	
294-2	LIVER	2540	726.4	35	1.43	10.0	1.52	6.3	.27	12.0	
294-3	LUNG	1430	1014.8	70							
294-7	SAMPLE RETURNED NOT ANALYZED										
295-2	LIVER	1500	910.3	29	1.40	18.0	1.54	7.7	.24	14.0	
295-3	LUNG	330	— 762.0	36			.16	15.0	.26	29.0	
296-2	LIVER	1100	843.0	52	2.26	4.3	2.60	1.8	.22	3.8	
296-3	LUNG	425	405.1	56							
297-2	LIVER	1450	608.8	59	2.60	3.8	2.63	4.6	.15	6.4	
297-3	LUNG	525	523.6	45	1.04	6.8	1.26	5.0	.11	15.0	
297-7	SAMPLE RETURNED NOT ANALYZED										

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
298-2	LIVER	1250	534.3	61			.13	5.8	.28	9.4	
298-3	LUNG	620	606.2	60	1.26	5.2	1.36	3.0	.17	5.4	
299-2	LIVER	1925	620.9	68	1.04	5.8	1.15	5.1	.22	10.0	
299-3	LUNG	550	421.0	53							
300-2	LIVER	1400	694.5	76	.80	5.6	.98	6.8	,24	8.8	
300-3	LUNG	750	579.1	73							
301-2	LIVER	1620	1206.4	65	.52	9.4					
301-3	LUNG	590	377.5	75			.17	9.4	.23	14.0	
301-8	LUNG	490	349.3	60	.12	26.0	.06	11.0	.18	25.0	
302-2	LIVER	1200	1095.6	51	1.11	6.1					
302-3	LUNG	320	304.9	56							
302-8	LUNG	420	377.0	60	.13	20.0	.11	2.5	.14	5.7	
303-2	LIVER	1140	605.5	53	2.28	4.3	2.66	5.5	.15	5.2	
303-3	LUNG	360	319.7	43			.59	2.7	.18	6.4	
304-2	LIVER	1700	725.5	61	2.25	4.0	2.22	2.2	.16	4.5	
304-3	LUNG	450	475.5	49			.10	8.3	.14	20.0	
305-2	LIVER	1000	720.2	51	1.06	7.1					
305-3	LUNG	400	373.8	46							
306-2	LIVER	1680	949.0	62	2,43	3.2					
306-3	LUNG	480	455.6	53							
306-7	SAMPLE RETURNED NOT ANALYZED										
306-8	LUNG	520	516.5	61	.09	26.0	.16	5.9	.13	16.0	
307-2	LIVER	700	672.7	47	2.08	7.0	2.17	2.7	.22	5.1	
307-3	LUNG	510	293.1	43							
307-8	LUNG	420	541.6	45			.13	6.6	.21	14.0	
308-2	LIVER	1220	1035.2	53	1.37	8.8	1.52	5.1	.24	8.8	
308-3	LUNG	360	927.3	36							
309-2	LIVER	1370	796.6	45	3.49	6.7	3.75	1.4	.20	2.8	
309-3	LUNG	420	685.3	39							
310-2	LIVER	1400	642.4	39	2.09	11.0	3.12	8.4	.23	16.0	
310-3	LUNG	600	564.2	44							
310-7	SAMPLE RETURNED NOT ANALYZED										
311-2	LIVER	2200	539.6	46	.30	28.0					
311-3	LUNG	750	645.4	47			.32	8.7	.17	22.0	
311-7	SAMPLE RETURNED NOT ANALYZED										
312-2	LIVER	1600	1168.0	53	2.41	7.1	2.59	.4	.19	.7	
312-3	LUNG	450	403.7	43			.33	9.7	.15	25.0	
313-2	LIVER	2120	1024.4	48	1.49	8.0					
313-3	LUNG	720	689.8	49			.13	7.4	.16	15.0	
313-7	SAMPLE RETURNED NOT ANALYZED										

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
314-2	LIVER	1400	447.9	51	.74	14.0	.74	1.3	.19	2.5	
314-3	LUNG	350	— 653.7	45			.22	9.1	.14	16.0	
315-2	LIVER	1800	698.6	37	1.35	12.0	1.38	2.3	.19	4.7	
315-3	LUNG	650	668.5	37			.41	11.0	.22	22.0	
316-2	LIVER	1100	511.9	45	.92	12.0	.82	10.0	.17	21.0	
316-3	LUNG	320	— 467.1	58							
317-2	LIVER	1200	762.0	66	1.16	5.2	1.36	3.5	.20	6.6	
317-3	LUNG	850	699.8	47			.20	5.5	.16	12.0	
318-2	LIVER	1500	586.7	44	5.32	6.1	2.82	3.5	.23	6.9	
318-3	LUNG	575	536.1	25			.28	8.9	.16	20.0	
319-2	LIVER	1950	1538.9	36	.55	11.0					
319-3	LUNG	340	— 1007.0	36							
320-2	LIVER	1480	1084.8	25	2.22	11.0					
320-3	LUNG	370	353.5	60							
321-2	LIVER	1990	874.9	41	3.60	6.9	4.08	1.6	.20	3.2	
321-3	LUNG	490	484.5	73	.84	11.0	.44	3.5	.13	8.8	
322-2	LIVER	1690	978.3	43	1.41	5.8	1.72	3.7	.14	8.2	
322-3	LUNG	820	407.1	43							
323-2	LIVER	1610	686.0	19	.87	16.0					
323-3	LUNG	525	459.5	23							
324-2	LIVER	450	688.9	53	1.36	5.3	1.60	3.0	.22	4.8	
324-3	LUNG	600	365.9	55							
325-2	LIVER	980	739.4	61	1.49	4.8	1.81	2.9	.19	5.7	
325-3	LUNG	460	368.3	48	.22	17.0	.28	11.0	.24	18.0	
326-2	LIVER	715	715.3	57			.27	13.0	.19	21.0	
326-3	LUNG	750	721.9	13			.65	14.0	.20	26.0	
327-2	LIVER	1820	705.5	26			.24	7.7	.22	15.0	
327-3	LUNG	770	652.0	58	2.68	6.9	1.22	2.3	.19	4.4	
327-7	SAMPLE RETURNED NOT ANALYZED										
327-8	LUNG	830	726.3	44	.19	26.0	.21	4.9	.21	9.9	
328-2	LIVER	1400	1041.7	36	2.63	8.9	3.04	1.1	.19	2.2	
328-3	LUNG	440	— 1102.9	27							
329-2	LIVER	2400	525.5	16	.62	18.0					
329-3	LUNG	530	— 1087.1	29							
329-7	LIVER	2400	962.7	36	1.62	10.0	1.49	3.0	.20	6.1	
330-2	LIVER	1890	1068.5	50	.73	11.0					
330-3	LUNG	610	598.8	44							
331-2	LIVER	3050	691.5	30							
331-3	LUNG	700	— 1195.1	36			.15	14.0	.24	18.0	
331-7	SAMPLE RETURNED NOT ANALYZED										

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
332-2	LIVER	2350	1647.5	42	3.63	7.0	3.53	1.3	.18	2.5	
332-3	LUNG	400	— 621.8	45			.40	7.2	.23	12.0	
333-2	LIVER	1580	676.7	49	1.85	4.7	2.03	1.3	.18	2.4	
333-3	LUNG	720	626.6	65	.51	19.0					
334-2	LIVER	1540	751.5	23	1.08	16.0	.58	5.3	.21	11.0	
334-3	LUNG	310	— 1012.5	19			1.13	4.5	.17	9.7	
334-7	SAMPLE RETURNED		NOT ANALYZED								
335-2	LIVER	2300	694.7	16	.53	27.0	1.12	2.9	.20	5.6	
335-3	LUNG	760	653.5	19							
335-7	SAMPLE RETURNED		NOT ANALYZED								
336-2	LIVER	4600	1295.6	40	.83	8.0					
336-3	LUNG	860	— 1043.4	32			.10	4.9	.15	11.0	
336-7	LIVER	4600	1401.6	20	1.45	15.0	1.55	3.2	.19	6.1	
337-2	LIVER	1770	767.4	19							
337-3	LUNG	320	— 896.3	47	1.03	6.7	1.18	4.5	.17	9.5	
337-7	SAMPLE RETURNED		NOT ANALYZED								
338-2	LIVER	1100	629.3	55	2.16	8.7	2.35	.9	.16	1.7	
338-3	LUNG	350	336.4	0							
338-7	SAMPLE RETURNED		NOT ANALYZED								
338-8	LUNG	400	383.5	55	.14	26.0					
339-2	LIVER	1500	644.5	55	1.59	4.4	2.12	3.3	.18	6.5	
339-3	LUNG	700	617.6	49	.19	19.0					
339-7	SAMPLE RETURNED		NOT ANALYZED								
339-8	LUNG	710	— 1059.6	37	.25	24.0	.22	5.1	.11	9.0	
340-2	LIVER	1510	674.2	62	1.48	4.0	1.55	1.0	.17	2.0	
340-3	LUNG	1020	748.6	40			.33	3.3	.19	6.6	
340-7	SAMPLE RETURNED		NOT ANALYZED								
340-8	LUNG	620	640.1	54	.26	13.0	.30	3.7	.14	8.6	
341-2	LIVER	2000	1504.2	25			.29	5.4	.21	7.8	
341-3	LUNG	260	— 897.3	58			.11	16.0	.14	28.0	
342-2	LIVER	1020	693.1	76	1.97	5.2	2.24	4.6	.22	10.0	
342-3	LUNG	490	— 565.3	73			.16	2.1	.12	5.6	
343-2	LIVER	1450	682.5	65	2.96	3.4	3.18	1.7	.20	3.2	
343-3	LUNG	340	— 755.2	63	.26	6.6	.30	4.7	.17	10.0	
344-2	LIVER	1300	761.6	52	5.51	2.9	6.31	3.2	.21	5.8	
344-3	LUNG	900	836.6	53	.44	7.4	.46	4.0	.12	9.6	
345-2	LIVER	1300	1306.7	60	2.89	3.6	2.73	3.9	.19	6.0	
345-3	LUNG	470	515.0	50							
346-2	LIVER	1630	537.2	54	2.09	3.7	2.19	1.6	.17	3.2	
346-3	LUNG	610	527.2	58	.30	10.0					

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
347-2	LIVER	1300	621.2	45	.31	13.0	.34	11.0	.17	24.0	
347-3	LUNG	580	493.8	56	2.14	3.6	2.10	1.8	.20	3.4	
348-2	LIVER	1120	902.9	19	2.02	13.0					
348-3	LUNG	400	— 951.9	27							
349-2	LIVER	1810	526.6	58	2.08	3.7	2.21	1.1	.19	2.1	
349-3	LUNG	600	537.7	54	.78	11.0	.52	3.7	.10	10.0	
349-7	SAMPLE RETURNED NOT ANALYZED										
350-2	LIVER	1580	1107.9	49	1.27	5.0					
350-3	LUNG	1250	1178.0	46							
351-2	LIVER	1250	857.0	44	7.97	4.5	3.76	1.3	.22	2.4	
351-3	LUNG	410	423.5	53	.27	12.0					
352-2	LIVER	1330	1048.4	23	2.98	8.9	3.75	1.3	.19	2.4	
352-3	LUNG	450	— 1198.4	46							
353-2	LIVER	1100	319.0	70	.99	7.3	.99	4.0	.22	6.9	
353-3	LUNG	600	471.5	56			.21	3.4	.13	8.4	
354-2	LIVER	600	497.7	70	.91	5.4					
354-3	LUNG	200	— 729.3	43							
355-2	LIVER	1300	853.8	55	3.81	3.0	4.27	3.6	.23	7.5	
355-3	LUNG	770	551.6	60	.20	13.0	.23	15.0	.25	19.0	
356-2	SAMPLE RETURNED NOT ANALYZED										
356-3	LUNG	740	687.3	51			.34	9.5	.17	9.0	
356-7	LIVER	1300	512.8	64	1.33	4.3	1.33	3.1	.19	5.5	
357-2	LIVER	1510	857.0	31	7.48	5.6	3.66	5.1	.24	10.0	
357-3	LUNG	450	520.5	38			.25	9.5	.17	17.0	
358-2	LIVER	1750	812.9	50	.52	8.5					
358-3	LUNG		1170.2	57							
359-2	LIVER	4200	1164.3	53	.46	8.0					
359-3	LUNG		675.0	63	.15	17.0					
359-9	SAMPLE RETURNED NOT ANALYZED										
360-2	LIVER	2250	845.2	49	1.31	10.0					
360-3	LUNG	430	← 1175.1	60	.63	14.0	.51	5.3	.08	7.5	
360-7	SAMPLE RETURNED NOT ANALYZED										
361-2	LIVER	1200	609.5	72	.30	16.0	.30	6.5	.18	14.0	
361-3	LUNG		378.4	69							
361-7	SAMPLE RETURNED NOT ANALYZED										
362-2	LIVER	1300	618.1	69	2.12	4.8	2.35	2.7	.20	5.4	
362-3	LUNG	430	379.2	60	.22	19.0	.22	2.7	.14	6.4	
363-2	LIVER	2600	950.1	78	.57	9.8	.65	2.9	.20	4.5	
363-3	LUNG	750	583.8	76	.16	21.0	.14	2.4	.13	5.3	
363-8	LUNG	480	446.7	22							

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
364-2	LIVER	1295	626.6	69	.66	9.2					
364-3	LUNG	310	275.8	67							
365-2	LIVER	2400	723.4	42	1.35	7.8	1,50	9.8	.21	18.0	
365-3	LUNG	1000	528.8	51			.08	9.7	.11	26.0	
366-2	LIVER	950	932.1	29	2.78	5.3					
366-3	LUNG	700	654.6	40							
366-8	LUNG	600	514.4	12							6
367-2	LIVER		769.5	41	2.18	4.9	2.39	7.0	.20	13.0	
367-3	LUNG	620	687.1	18							
367-7	LIVER		432.0	52	1.49	5.0	1.60	7.2	.22	6.6	
368-2	LIVER	2100	725.6	31	2.22	5.5	2.78	4.7	.11	15.0	5
368-3	LUNG		1203.0	31							
368-7	LIVER	2100	770.6	45	.99	6.6					
369-2	LIVER	1100	767.7	44	2.56	4.4	2.60	1.6	.21	2.9	
369-3	LUNG	820	765.9	33			.13	5.3	.08	17.0	
370-2	LIVER	2400	767.8	43							
370-3	LUNG	500	419.9	67	1.03	6.0	1.16	3.9	.11	11,0	
370-7	LIVER	2400	764.2	13							
371-2	LIVER	1150	954.9	21	1.64	12.0	1.64	2.0	.19	3.7	
371-3	LUNG	560	527.7	60							
372-2	LIVER	1650	1028.6	73	.43	8.1					
372-3	LUNG	660	630.0	72							
373-2	LIVER	1650	1102.9	66	4.32	5.9	4.40	.8	.18	1.1	
373-3	LUNG	950	904.3	69	.59	11.0					
374-2	LIVER	1800	797.6	70	3.49	3.4	3.43	2.6	.20	5.6	
374-3	LUNG	650	689.7	67							
375-2	LIVER	1200	484.0	71	3.48	3.4	3.18	3.0	.06	11.0	4
375-3	LUNG	400	332.1	66	.46	8.7					1
375-7	LIVER	1200	470.5	60	1.31	7.4	1.22	7.8	.19	16.0	
375-8	LUNG	370	400.3	55							
375-9	BLOOD		97.7	52			.05	14.0	.22	25.0	
376-2	LIVER	1360	665.0	52	1.25	5.5	1.24	1.1	.16	1.6	
376-3	LUNG	980	884.0	11							
377-2	LIVER	900	846.2	62	1.53	4.5	1.56	1.9	.18	3.3	
377-3	LUNG	420	523.7	52	.15	21.0	.22	11.0	.16	28.0	
378-2	LIVER	2020	703.4	69	.41	7.5	.18	6.6	.25	11.0	
378-3	LUNG	780	733.6	47			.19	7.6	.20	15.0	
379-2	LIVER	2540	1069.6	60	.80	6.0					
379-3	LUNG	560	530.5	60							
379-8	LUNG	460	422.3	18			.14	10.0	.23	18.0	

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
380-2	LIVER	820	666.6	59	.52	7.6	.45	1.7	.20	3.3	
380-3	LUNG	920	900.3	52							
381-2	LIVER	2100	1931.4	50	6.73	2.6	6.60	1.2	.18	2.8	
381-3	LUNG	600	— 1160.7	63	.19	11.0	.21	3.8	.10	12.0	
382-2	LIVER	2300	773.2	36	.63	10.0	.96	5.7	.26	9.5	
382-3	LUNG	600	722.6	32							
382-7	SAMPLE RETURNED NOT ANALYZED										
383-2	LIVER	1900	1686.7	20	2.21	7.4	2.38	4.5	.20	5.4	
383-3	LUNG	450	— 768.2	69	.12	20.0					
384-2	LIVER	1200	851.6	12	2.99	8.1					
384-3	LUNG	580	446.5	56	1.60	4.6	1.73	2.6	.04	15.0	1
384-6	LUNG	440	503.3	66	.13	19.0					
385-2	LIVER	1650	1416.7	66	4.51	3.1	4.75	1.3	.19	2.8	
385-3	LUNG		722.6	62			.10	5.0	.14	13.0	
386-2	LIVER	1300	1126.1	63	3.50	3.4	3.52	.7	.20	1.2	
386-3	LUNG		967.0	43			.12	5.6	.17	12.0	
387-2	LIVER	1000	932.1	46	1.70	5.0	1.61	2.7	.20	6.0	
387-3	LUNG		790.7	40	.17	23.0					
388-2	LIVER	1680	1468.2	45	.37	12.0					
388-3	LUNG	830	380.4	42	.12	25.0					
389-2	LIVER	1000	831.6	67	2.35	4.0	2.48	1.8	.20	2.2	
389-3	LUNG	1100	575.7	33			.17	8.6	.19	17.0	
390-2	LIVER	1400	1131.7	47	.93	7.1					
390-3	LUNG	750	532.4	44	2.19	7.5	2.23	.9	.01	7.4	4
390-6	LUNG	580	490.4	74							
391-2	LIVER	1500	1025.0	50	1.96	4.4	2.07	3.6	.16	9.2	
391-3	LUNG	480	503.9	40	.92	7.3					1
391-8	LUNG	440	361.0	43	.16	22.0	.17	3.2	.09	9.5	
392-2	LIVER	1280	766.2	49	3.13	3.7	3.10	1.7	.18	7.5	
392-3	LUNG	500	475.6	46	.11	26.0	.12	4.3	.16	6.3	
393-2	LIVER	1240	697.1	29	2.21	5.9	2.36	2.0	.18	4.1	
393-3	LUNG	580	542.7	17							
394-2	LIVER	1750	769.1	52	.90	6.9	1.21	3.5	.24	7.0	
394-3	LUNG	710	746.7	55	.17	16.0					
395-2	LIVER	1700	971.1	46	2.73	4.1					
395-3	LUNG	950	932.5	17	.78	23.0	.41	6.6	.22	18.0	
396-2	LIVER	1600	765.9	50	2.77	3.8	2.97	1.4	.21	2.9	
396-3	LUNG	500	466.2	50	.17	20.6					
397-2	LIVER	1150	684.1	41	.34	15.0	.44	4.8	.19	7.7	
397-3	LUNG	200	201.0	55							

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
398-2	LIVER	1600	595.5	28	.75	12.0					
398-3	LUNG	1250	1223.1	41							
399-2	LIVER	2300	711.5	55	.39	8.5					
399-3	LUNG	350	319.4	27							6
400-2	LIVER	1600	1110.3	25	3.12	8.7	3.36	1.0	.18	1.8	
400-3	LUNG	260	265.5	69	.11	17.0	.10	8.4	.10	27.0	
401-2	LIVER	1400	664.4	75	.66	5.4	.60	3.4	.20	6.5	
401-3	LUNG	750	689.2	55			.43	.6	.07	2.9	
402-2	LIVER	1500	799.1	65	2.27	6.1	.97	2.6	.19	5.5	
402-3	LUNG	475	484.5	72			.03	6.6	.14	15.0	
403-2	LIVER	1100	666.2	53	2.65	5.8	3.04	1.0	.19	1.9	
403-3	LUNG	900	681.0	66	.29	11.0	.29	1.7	.12	4.4	
404-2	LIVER	1100	666.3	54	3.65	3.5	4.25	1.8	.20	3.4	
404-3	LUNG	450	500.1	57	.22	16.0					
405-2	LIVER	1500	909.4	36	2.92	6.8					
405-3	LUNG		704.2	57							
406-3	LUNG	430	385.5	55							
407-2	LIVER	1000	777.8	64	2.38	3.7	3.24	1.6	.24	3.1	
407-3	LUNG	220	— 258.2	45	.16	29.0	.11	21.0	.12	32.0	
408-2	LIVER	1940	894.1	15	.99	20.0	.45	3.1	.19	5.7	
408-3	LUNG	1670	603.8	48							
408-7	SAMPLE COMBINED WITH SAMPLE408-2										
409-2	LIVER	725	496.5	44							
409-3	LUNG	300	296.1	63							
410-2	LIVER	1910	829.6	52	1.18	8.4	1.27	2.7	.19	4.8	
410-3	LUNG	1000	801.9	55			.17	5.5	.20	12.0	
411-2	LIVER	1050	764.0	57	2.00	6.2					
411-3	LUNG	440	431.6	66			.06	8.0	.21	17.0	
412-2	LIVER	1600	674.5	60	.26	10.0					
412-3	LUNG	700	637.8	48			.13	7.9	.20	9.5	
413-2	LIVER	1400	683.8	54	3.15	3.7	3.26	1.5	.19	2.8	
413-3	LUNG		498.1	34							
414-2	LIVER	2700	1072.4	14	2.34	8.7	2.41	3.4	.20	5.3	
414-3	LUNG	380	370.0	88	.42	11.0					
415-2	LIVER	1380	1172.0	26	1.82	10.0	2.55	7.1	.23	9.2	
415-3	LUNG	1070	681.3	29	.17	25.0					6
415-8	LUNG	540	— 787.6	20	.26	19.0					
416-2	LIVER	1720	623.8	44	1.47	5.3					6
416-3	LUNG	510	485.2	39	.19	23.0					6
416-7	LIVER	1720	557.3	52	1.29	5.3	1.36	1.8	.19	4.1	

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
416-8	LUNG	500	431.7	15			.12	6.6	.12	17.0	
417-2	LIVER	1150	876.3	57	.22	12.0	.30	9.7	.24	17.0	
417-3	LUNG	620	548.8	59	.12	18.0					
418-2	LIVER	1200	529.0	43	1.86	4.9	2.10	1.4	.10	2.4	5
418-3	LUNG	900	799.7	52	.26	13.0	.22	3.1	.14	8.1	
418-7	LIVER	1200	465.4	44	1.22	6.2	1.12	2.4	.19	4.7	
419-2	LIVER	1100	1029.0	42	1.59	5.7					
419-3	LUNG	720	621.9	22	.48	23.0					
420-2	LIVER	1500	1385.1	34	.96	8.6	1.03	3.2	.17	7.4	
420-3	LUNG	600	437.7	37	.27	26.0					
420-7	SAMPLE COMBINED WITH SAMPLE420-2										
420-8	LUNG	600	473.1	21	.31	27.0					
421-2	LIVER	900	536.1	32	.58	15.0					
421-3	LUNG	630	582.9	50							
422-2	LIVER	1500	659.7	46	.19	20.0					
422-3	LUNG	340	309.3	52							
423-2	SAMPLE RETURNED NOT ANALYZED										
423-3	SAMPLE RETURNED NOT ANALYZED										
424-2	LIVER	2300	1422.6	26							
424-3	LUNG	420	391.7	43							
424-7	SAMPLE COMBINED WITH SAMPLE424-2										
425-2	LIVER	1075	780.7	46	.49	15.0					
425-3	LUNG	520	526.5	65	.20	12.0	.25	6.7	.17	13.0	
426-2	LIVER	1500	866.9	68	2.71	3.4	3.21	2.4	.24	4.1	
426-3	LUNG	440	417.6	54	.39	9.8					
427-2	LIVER	1000	587.7	15	3.43	12.0	2.71	2.3	.20	4.3	
428-2	LIVER	2500	837.4	49	.76	7.3	.95	7.0	.26	13.0	
428-3	LUNG	500	— 677.4	38							
429-2	LIVER	2600	112.2	34							
429-3	LUNG	800	646.8	34							
430-2	SAMPLE RETURNED NOT ANALYZED										
430-3	SAMPLE RETURNED NOT ANALYZED										
430-7	SAMPLE RETURNED NOT ANALYZED										
431-2	SAMPLE RETURNED NOT ANALYZED										
431-3	SAMPLE RETURNED NOT ANALYZED										
431-7	SAMPLE RETURNED NOT ANALYZED										
432-2	SAMPLE RETURNED NOT ANALYZED										
432-3	SAMPLE RETURNED NOT ANALYZED										
433-2	SAMPLE RETURNED NOT ANALYZED										
433-3	SAMPLE RETURNED NOT ANALYZED										

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
434-2	SAMPLE RETURNED NOT ANALYZED										
434-3	SAMPLE RETURNED NOT ANALYZED										
435-2	SAMPLE RETURNED NOT ANALYZED										
435-3	SAMPLE RETURNED NOT ANALYZED										
436-2	SAMPLE RETURNED NOT ANALYZED										
436-3	SAMPLE RETURNED NOT ANALYZED										
437-2	SAMPLE RETURNED NOT ANALYZED										
437-3	SAMPLE RETURNED NOT ANALYZED										
438-2	SAMPLE RETURNED NOT ANALYZED										
438-3	SAMPLE RETURNED NOT ANALYZED										
438-7	SAMPLE RETURNED NOT ANALYZED										
439-2	LIVER	1390	1266.0	34	3.76	3.9	3.92	1.6	.17	3.1	
439-3	LUNG	1310	1134.7	47	.92	5.8	.96	2.4	.18	5.5	
439-7	SAMPLE COMBINED WITH SAMPLE439-2										
439-8	LUNG	1120	1158.9	46	.25	21.0					
440-2	LIVER	1150	669.4	42	1.09	11.0					
440-3	LUNG	450	366.7	27			.06	11.0	.12	27.0	
441-2	LIVER	2300	684.0	58	1.07	9.5					
441-3	LUNG	600	592.8	66	.26	11.0					
442-2	LIVER	2500	675.4	55	.09	25.0					
442-3	LUNG	550	456.6	60							
443-2	LIVER	660	643.8	51	.71	12.0	.77	2.1	.19	4.8	
443-3	LUNG	320	413.0	56							
444-2	LIVER	1700	691.8	38			.12	4.0	.16	5.8	
444-3	LUNG	350	329.5	57			.05	4.0	.11	11.0	
445-2	LIVER	1400	676.0	30	.30	23.0	.37	2.7	.20	5.8	
445-3	LUNG	1160	1150.9	41			.03	7.1	.15	15.0	
446-2	LIVER	1040	660.9	54	1.81	4.5	1.60	1.8	.16	2.6	
446-3	LUNG	370	320.0	61	.12	16.0	.12	7.5	.16	17.0	
447-2	LIVER	1750	936.6	61	.99	10.0	1.12	1.8	.19	4.0	
447-3	LUNG	420	403.2	38							
447-7	LIVER	1750	751.7	59	.74	9.8	.83	2.3	.18	4.5	3
447-8	LUNG	420	541.0	20							6
448-2	LIVER	1400	1001.0	58	2.15	4.0	2.25	.9	.18	2.0	
448-3	LUNG	920	754.9	56	.26	11.0					
449-2	SAMPLE RETURNED NOT ANALYZED										
449-3	SAMPLE RETURNED NOT ANALYZED										
450-2	SAMPLE RETURNED NOT ANALYZED										
450-3	SAMPLE RETURNED NOT ANALYZED										
451-2	SAMPLE RETURNED NOT ANALYZED										

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
451-3	SAMPLE RETURNED NOT ANALYZED										
452-2	LIVER	1700	1420.9	0							
452-3	SAMPLE RETURNED NOT ANALYZED										
453-2	LIVER	1350	664.4	40	.96	10.0	1.03	1.4	.20	2.6	
453-3	LUNG	280	— 404.5	38							
454-2	LIVER	1200	952.3	53	3.61	3.7	3.86	1.4	.20	2.4	
454-3	LUNG	600	511.6	56	.23	13.0	.25	6.9	.10	13.0	
455-2	LIVER	1600	1471.4	48	2.20	4.6	2.74	5.4	.22	11.0	
455-3	LUNG	750	738.5	47			.13	12.0	.16	20.0	
456-2	LIVER	1150	868.5	43	3.05	7.2	3.34	.8	.19	1.2	
456-3	LUNG	300	— 444.3	57							
457-2	SAMPLE RETURNED NOT ANALYZED										
457-3	SAMPLE RETURNED NOT ANALYZED										
457-7	SAMPLE RETURNED NOT ANALYZED										
458-2	SAMPLE RETURNED NOT ANALYZED										
458-3	SAMPLE RETURNED NOT ANALYZED										
459-2	SAMPLE RETURNED NOT ANALYZED										
459-3	SAMPLE RETURNED NOT ANALYZED										
460-2	SAMPLE RETURNED NOT ANALYZED										
460-3	SAMPLE RETURNED NOT ANALYZED										
460-7	SAMPLE RETURNED NOT ANALYZED										
460-8	SAMPLE RETURNED NOT ANALYZED										
460-9	SAMPLE RETURNED NOT ANALYZED										
461-2	SAMPLE RETURNED NOT ANALYZED										
461-3	SAMPLE RETURNED NOT ANALYZED										
462-2	SAMPLE RETURNED NOT ANALYZED										
462-3	SAMPLE RETURNED NOT ANALYZED										
462-7	SAMPLE RETURNED NOT ANALYZED										
463-2	SAMPLE RETURNED NOT ANALYZED										
463-3	SAMPLE RETURNED NOT ANALYZED										
464-2	SAMPLE RETURNED NOT ANALYZED										
464-3	SAMPLE RETURNED NOT ANALYZED										
465-2	SAMPLE RETURNED NOT ANALYZED										
465-3	SAMPLE RETURNED NOT ANALYZED										
466-2	SAMPLE RETURNED NOT ANALYZED										
466-3	SAMPLE RETURNED NOT ANALYZED										
467-2	SAMPLE RETURNED NOT ANALYZED										
467-3	SAMPLE RETURNED NOT ANALYZED										
468-2	LIVER	1360	649.3	43	1.49	5.8	1.70	1.2	.18	2.3	
468-3	LUNG	560	535.2	56	.40	9.0					

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
469-2	LIVER	1125	983.1	54	1.41	5.0	1.37	1.3	.19	2.9	
469-3	LUNG	400	281.6	46			.05	12.0	.20	24.0	6
469-8	LUNG	330	312.3	27							
470-2	LIVER	1900	769.4	40	.83	12.0					
470-3	LUNG	1775	1030.1	42	.79	7.4	.86	3.2	.14	6.1	
471-2	LIVER	970	727.9	50	.25	14.0	.31	8.6	.25	16.0	
471-3	LUNG	595	433.9	54							
472-2	LIVER	7210	703.4	48							
472-3	LUNG	650	570.1	28			.11	4.9	.13	9.9	
473-2	LIVER	930	741.0	27	3.66	7.7	4.50	2.1	.20	3.6	
473-3	LUNG	320	384.2	65	.15	21.0					
473-8	LUNG	670	448.7	60	.17	13.0					
474-2	LIVER	1300	1018.3	56	.36	16.0	.40	7.5	.16	16.0	
474-3	LUNG	730	652.4	48	.34	16.0					
475-2	LIVER	1445	783.5	44	.49	16.0	.55	14.0	.22	21.0	
475-3	LUNG	645	632.7	49	3.88	3.7	3.95	.7	.01	6.5	5
475-8	LUNG	750	719.1	35			.12	11.0	.22	18.0	
476-2	LIVER	1300	624.8	62	2.09	4.1	2.11	1.3	.18	1.9	
476-3	LUNG	590	629.3	57	.17	17.0	.21	4.9	.19	8.8	
477-2	LIVER	1200	1153.9	43	.41	12.0	.59	5.9	.19	13.0	2
477-3	LUNG	560	491.1	32	.30	24.0	.26	2.1	.12	5.7	6
478-2	SAMPLE	RETURNED	NOT ANALYZED								
478-3	SAMPLE	RETURNED	NOT ANALYZED								
479-2	SAMPLE	RETURNED	NOT ANALYZED								
479-3	SAMPLE	RETURNED	NOT ANALYZED								
479-7	SAMPLE	RETURNED	NOT ANALYZED								
480-2	SAMPLE	RETURNED	NOT ANALYZED								
480-3	SAMPLE	RETURNED	NOT ANALYZED								
481-2	SAMPLE	RETURNED	NOT ANALYZED								
481-3	SAMPLE	RETURNED	NOT ANALYZED								
482-2	SAMPLE	RETURNED	NOT ANALYZED								
482-3	SAMPLE	RETURNED	NOT ANALYZED								
483-2	LIVER	1400	602.7	31	1.05	8.3	1.03	5.1	.18	11.0	6
483-3	LUNG	500	392.0	42			.09	14.0	.09	25.0	6
484-2	SAMPLE	RETURNED	NOT ANALYZED								
484-3	SAMPLE	RETURNED	NOT ANALYZED								
485-2	LIVER	2160	1494.7	44	1.75	5.0	1.86	1.6	.19	3.3	
485-3	LUNG	1100	996.1	48	.20	20.0	.21	5.5	.13	11.0	
486-2	LIVER	2300	636.1	49							
486-3	LUNG	770	675.9	58			.03	9.0	.14	19.0	

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
487-2	LIVER	1000	904.6	22	.30	26.0	.26	5.2	.19	11.0	
487-3	LUNG	320	312.5	64	.15	15.0	.13	4.8	.07	16.0	
487-8	LUNG	650	113.8	34			.08	9.1	.22	17.0	
488-2	SAMPLE RETURNED NOT ANALYZED										
488-3	SAMPLE RETURNED NOT ANALYZED										
489-2	LIVER	2800	678.7	44	.31	18.0	.38	1.9	.20	3.7	
489-3	LUNG	600	451.5	50			.09	4.1	.14	10.0	
490-2	LIVER	1800	864.5	39	.65	15.0	.63	1.8	.17	3.8	
490-3	LUNG	600	547.7	42	.20	21.0	.20	5.4	.15	14.0	
491-2	LIVER	1940	569.8	18	5.75	10.0	5.53	1.6	.04	6.3	4
491-3	LUNG	710	637.8	17			.16	5.5	.14	11.0	
491-7	LIVER	1940	981.1	22	1.59	14.0	2.02	1.4	.18	2.7	
491-8	LUNG	700	649.3	33	3.44	8.7	3.32	1.8	.01	8.2	1
492-3	SAMPLE RETURNED NOT ANALYZED										
493-2	LIVER	2600	1115.7	25	1.35	13.0	1.15	1.5	.18	2.9	
493-3	LUNG	940	896.9	12	.56	25.0	.69	3.4	.13	8.5	
493-7	LIVER	2600	853.6	33	2.16	5.5	2.11	.9	.07	2.9	5
494-2	LIVER	1600	643.8	34	1.37	6.6	1.29	1.4	.10	4.1	4
494-3	LUNG	500	527.5	50	4.17	3.5	4.11	.5	.01	3.7	5
494-7	LIVER	1600	621.5	45	.67	14.0	.69	.5	.18	1.0	
494-8	LUNG	750	661.4	48							
495-2	LIVER	1450	646.3	51	3.76	6.3	4.86	3.4	.13	9.8	1
495-3	LUNG	500	695.5	45	.17	28.0					
495-7	LIVER	1450	491.4	22	1.13	16.0	1.44	3.0	.19	4.3	
496-2	LIVER	1200	532.1	52	6.68	3.0	6.81	1.1	.05	2.6	1
496-3	LUNG	550	543.6	65	.17	13.0	.22	2.8	.14	6.5	
496-7	LIVER	1200	395.4	49	1.68	8.9	1.52	3.4	.19	7.1	
497-2	LIVER	1500	549.5	36	3.46	4.6	3.29	.7	.12	1.7	1
497-3	LUNG	600	563.5	36							
497-7	LIVER	1500	515.2	53	1.90	7.6	1.95	1.5	.19	2.5	
498-2	LIVER	1700	587.0	42	2.04	8.6	1.88	2.8	.17	4.0	
498-3	LUNG	680	1005.0	48	.15	26.0					
498-7	LIVER	1700	532.8	64	1.27	5.1	1.25	1.3	.17	2.6	
499-2	SAMPLE RETURNED NOT ANALYZED										
499-3	SAMPLE RETURNED NOT ANALYZED										
500-2	LIVER	1550	676.0	29	7.71	6.8	8.11	1.1	.04	4.0	1
500-3	LUNG	780	724.2	27			.30	5.6	.13	15.0	
500-7	LIVER	1550	637.0	50	2.55	7.5	2.32	1.3	.20	2.8	
501-2	SAMPLE RETURNED NOT ANALYZED										
501-3	SAMPLE RETURNED NOT ANALYZED										

TABLE 5

RESULTS OF ASSAYS FOR PLUTONIUM 239 PLUS 240

SAMPLE NUMBER	TISSUE TYPE	ORGAN WEIGHT (GMS)	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA ACTIVITY DPM/SMPL	APHA ERROR (PCT)	MASS SPEC ACTIVITY DPM/SMPL	M/S ERROR (PCT)	PU240/239 RATIO	RATIO ERROR (PCT)	SPIKE TYPE
502-2	LIVER	1250	688.4	37	1.60	14.0	1.68	13.0	.22	20.0	
502-3	LUNG	850	773.4	18			.19	5.8	.14	12.0	
503-2	LIVER	2000	474.0	20	.81	19.0					
503-3	LUNG	750	609.1	49	2.26	6.4	2.31	2.2	.02	10.0	4
503-8	LUNG	475	436.2	25							
504-2	SAMPLE RETURNED NOT ANALYZED										
505-2	LIVER	1300	381.5	14	.37	30.0	.39	6.5	.26	11.0	
505-3	LUNG	400	393.1	48	.23	25.0	.11	11.0	.13	27.0	
506-2	LIVER	4000	824.0	41	.37	18.0	.44	3.5	.20	6.9	
506-3	LUNG	340	334.2	49	.13	24.0	.10	3.4	.12	8.7	
506-7	LIVER	4000	1307.0	60	8.73	4.7	8.67	.7	.02	3.9	4
506-9	LIVER	4000	884.8	46	.45	15.0	.55	4.1	.18	6.6	
507-2	LIVER	2700	1006.9	43	.96	12.0	.88	3.5	.19	5.5	
507-3	LUNG	760	684.0	47			.13	5.2	.17	11.0	
507-7	LIVER	2700	879.3	37	6.19	3.8	6.23	.7	.03	5.1	5
508-2	LIVER	1000	672.0	48	1.79	8.5	1.72	.8	.18	1.7	
508-3	LUNG	370	371.0	43	.59	15.0	.57	1.9	.08	5.9	
509-2	LIVER	1100	506.1	44	.68	14.0	.62	2.6	.20	5.2	
510-2	SAMPLE RETURNED NOT ANALYZED										
510-3	SAMPLE RETURNED NOT ANALYZED										
511-2	SAMPLE RETURNED NOT ANALYZED										
511-3	SAMPLE RETURNED NOT ANALYZED										
512-2	SAMPLE RETURNED NOT ANALYZED										
512-3	SAMPLE RETURNED NOT ANALYZED										
513-2	SAMPLE RETURNED NOT ANALYZED										
513-3	SAMPLE RETURNED NOT ANALYZED										
514-2	SAMPLE RETURNED NOT ANALYZED										
514-3	SAMPLE RETURNED NOT ANALYZED										
515-2	SAMPLE RETURNED NOT ANALYZED										
515-3	SAMPLE RETURNED NOT ANALYZED										
516-2	SAMPLE RETURNED NOT ANALYZED										
516-3	SAMPLE RETURNED NOT ANALYZED										
517-2	SAMPLE RETURNED NOT ANALYZED										
517-3	SAMPLE RETURNED NOT ANALYZED										
518-2	LIVER	1370	1328.3	41	2.54	8.1	2.47	.9	.17	1.8	
518-3	LUNG	920	843.7	38			.11	2.9	.10	7.0	
519-2	LIVER	1000	904.6	62	.16	16.0	.15	2.6	.18	4.6	
519-3	LUNG	600	691.9	65			.01	12.0	.17	26.0	
519-7	SAMPLE COMBINED WITH SAMPLE519-2										

RESULTS OF ASSAYS FOR PLUTONIUM 236 OR 238

The records of the alpha pulse height analyses for all the tissue samples for which Pu 239+240 analyses are reported in Table 5, were also analyzed at MCL for the presence of Pu 236 or Pu 238. Whenever a valid measurement significantly different from background was found, the data are included in Table 6, regardless of whether or not the tissues were actually spiked with these isotopes. (See the discussion of the occurrence of Pu 238 in the atmosphere under Quality Assurance Results, pg. 119 and 120.)

Table 6 presents all the valid measurements of either Pu 236 or Pu 238 (or both) for the whole series of tissue samples. MCL reported Pu 236 or Pu 238 measurements for only the 108 samples listed in this Table (106-2 through 507-7); in the remainder, MCL detected no Pu 236 or Pu 238.

The headings in Table 6 have the same meanings as in Table 5 (qv), except as follows:

APHA Pu 236 (DPM/SMPL)

Plutonium 236 alpha activity in disintegrations per minute for the whole sample, as measured by alpha pulse height analysis. Blanks have same meaning as Table 5.

APHA Pu 238 (DPM/SMPL)

Plutonium 238 alpha activity in disintegrations per minute for the whole sample, as measured by alpha pulse height analysis. Blanks have same meaning as Table 5.

TABLE 6

RESULTS OF ASSAYS FOR PLUTONIUM 236 OR 238

SAMPLE NUMBER	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA PU-236 (DPM/SMPL)	PU-236 ERROR (PCT)	APHA PU-238 (DPM/SMPL)	PU-238 ERROR (PCT)	PU SPIKE TYPE
106-2	508.6	61	5.39	1.9	.09	25.0	3
106-3	446.4	38	1.25	8.1			3
108-8	338.3	61	.63	4.8			3
112-2	634.8	61	8.58	2.1	2.01	4.7	6
112-3	606.1	59	1.73	4.0	2.18	4.4	6
116-2	575.8	63	8.13	2.1			3
116-3	896.1	58	1.19	3.6			3
117-3	627.9	41			.49	9.3	2
117-8	178.0	17			.90	25.0	4
118-8	423.9	63	4.56	1.9			5
119-8	285.3	20	.67	17.0			5
120-8	410.2	38			1.28	13.0	2
121-3	250.0	34	1.06	15.0	5.08	8.2	6
121-8	485.2	42	.65	7.9	1.22	6.2	6
125-8	440.4	46	.84	8.3	2.07	7.6	6
130-8	334.7	49	.89	7.0	2.17	6.3	6
138-8	907.5	30			.70	18.0	4
143-8	268.9	76	2.86	2.8	5.33	3.2	6
145-3	528.4	62	1.95	3.5	1.10	5.8	6
146-8	801.2	19	1.85	9.5	1.45	15.0	6
151-3	501.5	70	4.01	1.5	3.23	4.7	6
152-3	695.9	59	2.91	3.1	.58	8.1	6
180-2	901.9	42			.14	19.0	
181-2	807.9	51			.28	25.0	
189-2	824.6	59			.32	18.0	
196-2	591.9	78			.09	25.0	
200-7	541.7	18			1.35	22.0	4
206-2	1046.1	87			.08	19.0	
212-7	604.3	36	.94	8.7	.26	19.0	5
228-2	743.1	80			.07	23.0	
229-2	390.0	48	1.22	7.2	1.40	9.4	6
244-2	559.9	68	4.47	2.0	.68	6.5	6
247-7	505.6	41	.32	24.0	.36	28.0	6
255-2	840.3	52			.40	19.0	
258-2	785.7	68			.08	26.0	
262-2	785.7	36			.52	26.0	
297-2	608.8	59			.13	19.0	
318-2	586.7	44			.12	27.0	
320-2	1084.8	25			.46	21.0	
321-2	874.9	41			.18	25.0	

TABLE 6

RESULTS OF ASSAYS FOR PLUTONIUM 236 OR 238

SAMPLE NUMBER	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA PU-236 (DPM/SMPL)	PU-236 ERROR (PCT)	APHA PU-238 (DPM/SMPL)	PU-238 ERROR (PCT)	PU SPIKE TYPE
322-2	978.3	43	.08	36.0			
322-3	407.1	43	.11	19.0			
323-2	686.0	19	.22	21.0			
324-2	688.9	53			.10	25.0	
324-3	365.9	55	.07	23.0			
325-2	739.4	61	.04	44.0			
325-3	368.3	48			.11	23.0	
330-2	1068.5	50	.07	50.0			
334-2	751.5	23	.57	11.0			
337-3	896.3	47	.07	23.0			
344-2	761.6	52			.28	9.9	
345-2	1306.7	60	.06	48.0			
347-3	493.8	56			.13	20.0	
349-2	526.6	58			.10	21.0	
350-2	1109.0	49			.12	20.0	
351-2	857.0	44			.12	24.0	
354-2	377.9	70			.12	16.0	
361-2	609.5	72	2.28	12.0			
366-8	514.4	12	4.02	9.9	4.19	10.0	6
368-2	725.6	31	1.80	5.1			5
374-2	797.6	70			.11	20.0	
375-2	484.0	71	.16	17.0	2.05	4.1	4
379-2	1069.6	60	.10	25.0			
381-2	1931.4	50			.20	15.0	
385-2	1416.7	66			.19	14.0	
386-2	1128.1	63			.10	22.0	
388-2	1468.2	45	.12	28.0			
389-2	831.8	67	.12	23.0	.13	20.0	
390-3	532.4	44			1.02	10.0	4
395-2	971.1	46			.10	26.0	
399-3	319.4	27	4.87	3.8	3.94	4.8	6
403-3	681.0	66	.15	11.0	.11	16.0	
404-2	666.3	54			.12	22.0	
405-2	909.4	36			.16	25.0	
413-2	683.8	54			.19	13.0	
414-3	370.0	88			.13	20.0	
415-3	681.3	29	5.60	2.4	2.63	4.7	6
416-2	623.8	44	8.51	1.9	5.42	3.3	6
416-3	485.2	39	1.57	4.1	.61	9.3	6
418-2	529.0	43	1.50	3.9			5

TABLE 6

RESULTS OF ASSAYS FOR PLUTONIUM 236 OR 238

SAMPLE NUMBER	SAMPLE WEIGHT (GMS)	TRACER YIELD (PCT)	APHA PU-236 (DPM/SMPL)	PU-236 ERROR (PCT)	APHA PU-238 (DPM/SMPL)	PU-238 ERROR (PCT)	PU SPIKE TYPE
439-2	700.3	34			.14	24.0	
446-2	660.9	54			.11	16.0	
447-7	751.7	59	10.70	2.5			3
447-8	541.0	20	5.14	7.2	3.76	9.8	6
454-2	952.3	53			.20	14.0	
455-2	1471.4	46			.14	16.0	
456-2	868.5	43			.12	30.0	
468-2	649.3	43			.19	20.0	
469-2	983.1	54			.09	19.0	
469-3	281.6	46	3.17	2.4	1.62	4.6	6
475-3	632.7	49	5.80	2.2			5
476-2	624.8	62			.09	19.0	
476-3	629.3	57			.24	12.0	
477-2	1153.9	43			5.96	3.4	2
477-3	491.1	32	.89	12.0	1.42	11.0	6
483-2	602.7	31	6.44	2.6	5.25	4.2	6
483-3	392.0	42	2.38	3.3	1.18	6.2	6
491-2	569.8	18			1.41	20.0	4
493-7	853.6	33	.40	11.0			5
494-2	643.8	34			.39	12.0	4
494-3	527.5	50	3.13	2.6			5
496-2	532.1	52			.11	19.0	1
496-3	543.6	65			.05	26.0	
497-2	549.5	36			.14	21.0	1
498-7	532.8	64			.06	25.0	
503-3	609.1	49			2.35	6.2	4
506-7	1307.0	60			3.76	5.7	4
507-7	879.3	37	2.66	3.9			5

QUALITY ASSURANCE

The quality assurance procedures for the Rocky Flats Human Burden Study were accomplished in two phases, a Qualifying Phase and a Continuing Phase. The purpose of the Qualifying Phase was to select one analytical laboratory. The Continuing Phase was used to monitor that laboratory's performance throughout the entire study.

Preparation of Spiked Tissue

The EMSL-LV laboratory staff prepared quality assurance samples by spiking tissue with isotopes Pu 239, Pu 236, and Pu 238. They also submitted a portion of the original unspiked tissue for analysis in order to determine the quantity of Pu 239 and Pu 240 originally present in the tissue from global fallout. The EMSL-LV staff felt quality assurance samples spiked with Pu 238 or Pu 236 would not require analysis of the original material due to the relatively small quantity of these isotopes in global fallout. (See Table 8 and Table 9, and discussion of Pu 238 in global fallout.) Standard solutions used to prepare the Q.A. samples were dilutions of stock solutions which had been standardized by the supplier and/or by EMSL-LV.

The standard solution used for preparing the qualifying samples came from Amersham-Searle and was standardized by them to within 2%. The plutonium 239 standard solution used for preparation of the Continuing Phase quality assurance samples came from the National Bureau of Standards where it had been standardized to within 1%. Both plutonium standards were certified better than 99% isotopically pure. The Pu 238 and Pu 236 standard solutions were standardized by EMSL-LV by windowless 2π alpha counting and comparison to an NBS certified americium 241 source (Sill, 1974). The Pu 236 was purified by EMSL-LV prior to standardization. Alpha spectrometric measurements of the Pu 238 and Pu 236 indicated that each of the two standards were better than 99% isotopically pure. Co-electroplating various combinations of the plutonium standards and alpha spectrometry measurements verified that calibration procedures among Amersham-Searle, NBS, and EMSL-LV were consistent within 3%.

Qualifying Phase

For the qualifying phase only, EPA staff in Las Vegas utilized locally obtained bovine liver and ashed bovine muscle which they spiked with a standardized plutonium tracer. They submitted these, together with blank samples, for analysis by the three laboratories, one of which was to be chosen to do all the plutonium measurements for this study. The results of these analyses are shown in Table 7. The agreement between the reported results from each laboratory and the known value for the standards was extremely good. The EPA awarded the contract to the McClellan Central Laboratory (Laboratory C) because it had acceptable accuracy and could provide mass spectrometric analyses to quantify the Pu 240/239 atom ratio. This ratio is useful in indicating the probable source of the plutonium (i.e. from nuclear bomb detonation or from nuclear weapons production).

Continuing Phase

The Continuing Phase quality assurance efforts involved submitting blind duplicate and spiked samples to the analytical laboratory during the five years of the study on a sporadic basis. These samples all consisted of actual human lung and liver tissues collected in Colorado for the study. The spiked samples were generally one of a pair of samples prepared using approximately one-half of a liver sample when sufficient tissue was available, or one of a pair of lungs. The UCMC staff prepared the paired samples and forwarded one of each

TABLE 7

RESULTS OF QUALIFYING PHASE

REFERENCE LABORATORY "A" RESULTS

EPA SAMPLE #	TYPE	KNOWN VALUE (dpm Pu 239+240/Sample)	REPORTED VALUE[a] (dpm Pu 239+240/Sample)
162520	Tissue Ash	0.58	0.65 ± 9%
24	"	5.85	5.88 ± 6%
28	"	2.34	2.53 ± 8%
32	"	Blank	0.04 ± 37%
36	"	0.22	0.23 ± 22%
162540	Acid Solution	1.17	1.40 ± 9%
44	"	5.85	6.77 ± 7%
48	"	11.7	12.3 ± 6%
52	"	Blank	<.02
56	"	0.22	0.23 ± 22%

REFERENCE LABORATORY "B" RESULTS

162521	Tissue Ash	0.58	0.58 ± 12%
25	"	5.85	5.37 ± 5%
29	"	2.34	2.29 ± 5%
33	"	Blank	0.005 ± 360%
37	"	0.22	0.28 ± 20%
162541	Acid Solution	1.17	0.96 ± 8%
45	"	5.85	4.51 ± 5%
49	"	11.7	11.7 ± 5%
53	"	Blank	<.02
57	"	0.22	0.15 ± 23%

REFERENCE LABORATORY "C" RESULTS[b]

162522	Tissue Ash	0.58	0.63 ± 11%
26	"	5.85	5.76 ± 4%
30	"	2.34	2.19 ± 7%
34	"	Blank	<.02
38	"	0.22	0.36 ± 15%

(Continued)

TABLE 7 (Continued)

LABORATORY "C," CONTINUED

162542	Acid Solution	1.17	L.I.A.(c)
46	"	5.85	4.12 ± 6%
50	"	11.7	L.I.A.
54	"	Blank	L.I.A.
58	"	0.22	0.37 ± 9%

(a) Error term is reported as coefficient of variation expressed as percentage,

$$\%\ C.V. = (S \div \bar{x}) \cdot 100$$

(b) Reference Laboratory "C" was selected, and performed all the plutonium measurements for this study.

(c) L.I.A. (Sample Lost In Analysis)

pair to be spiked to EMSL-LV for spiking and return to UCMC, so that it could be submitted to the MCL analytical laboratory in the regular way. Thus, the MCL staff made the plutonium measurements blind; they could not recognize a spiked sample before doing the plutonium analysis.

In preparing all but four of the spiked specimens, the EMSL-LV staff added measured amounts (0.020 ml to 1.00 ml) of standardized plutonium solutions (in 2 molar nitric acid) to cavities bored or sliced in the frozen or partially thawed tissue specimens (which weighed between 300 g and 1000 g). The solutions contained known quantities of plutonium isotopes, either Pu 239, Pu 238, or Pu 236. Some specimens were spiked with more than one solution. The resulting spike types (shown in Tables 5 and 6) are defined as follows: 1 = Pu 239, 2 = Pu 238, 3 = Pu 236, 4 = Pu 239 plus 238, 5 = Pu 239 plus 236, and 6 = Pu 236 plus 238. In order to contain the plutonium spike within the bulk of the specimen, after adding the solutions, the EMSL-LV staff covered or refilled the cavities with some of the tissue and refroze the whole specimen immediately. It was generally kept frozen during shipping and storage until finally placed in the pyrex beaker for drying and ashing at MCL.

The other four spiked specimens were prepared by the EMSL-LV staff in a similar manner except that the spike consisted of a weighed quantity (50 mg to 200 mg) of a standard soil, prepared by the Radiological and Environmental Sciences Laboratory, US Department of Energy, Idaho Falls, Idaho, containing highly refractory plutonium oxide particles (Sill, 1974). The purpose here was to verify that all forms of plutonium were being dissolved by the chemical procedures used. The EMSL-LV staff cut the specimens to be spiked in half while frozen, and after sprinkling the standard soil on the cut surface, they put the pieces back together again and kept them frozen until analysed.

One of these (specimen # 117-7) separated in shipment so that some of the standard soil could easily have been lost. (MCL reported less than 50% of the expected plutonium level in this case.) Because of this possible loss, this measurement was omitted from Table 12 and from the quality assurance analysis. The three spiked specimens which did not separate are shown at the beginning of Table 12 ; they are 111-7, 132-2 and 178-7. One of these (specimen 132-2) was reported as "no plutonium detected," meaning that the count was not significantly different from background. The Pu 239+240 levels reported for the refractory plutonium oxide spikes in 111-7 and 178-7 were 83% and 96% of the expected, respectively, which is as good as for the quality assurance specimens spiked with plutonium dissolved in nitric acid.

Two of the specimens spiked with nitric acid solutions (117-3 and 138-8) also separated during shipment; they had also been cut in half at EMSL-LV, had been spiked with a nitric acid solution of Pu 238, and frozen back together before shipment. For these, the reported level of Pu 238 was as close to the expected as for the specimens which did not separate during shipment. (See Table 9.A.)

Spikes with Plutonium 236 and Plutonium 238

Tables 8 and 9 show, respectively, the plutonium 236 and plutonium 238 quality assurance data based on alpha pulse height analysis done at MCL during the Continuing Phase of the quality assurance program. Samples 483-2, 483-3, 491-2, 493-7, 494-2, 494-3, 505-3 and 506-7 thawed after the spike was added. This could have resulted in a partial loss of spike before the sample reached the analytical laboratory. However, since they didn't seem grossly different from the other quality assurance results, the data have been included in Tables 8 and 9 with a notation.

TABLE 8(A)

PU 236 QUALITY ASSURANCE RESULTS FOR SPIKED SAMPLES
(See Figure 2 for Statistical Summary)

Sample Number	Spike Added (Dpm/Sample)(1)	Spike Observed (Dpm/Sample)(2)	Spike Observed ÷ Spike Added
106-2	5.90	5.39 ± 1.9%	0.90
106-3	1.18	1.25 ± 8.1%	1.06
108-8	0.71	0.63 ± 4.8%	0.89
112-2	9.44	8.58 ± 2.1%	0.91
112-3	1.78	1.73 ± 4.0%	0.97
116-2	8.86	8.13 ± 2.1%	0.92
116-3	1.48	1.19 ± 3.6%	0.80
118-8	4.72	4.56 ± 1.9%	0.97
119-8	1.18	0.67 ± 17.0%	0.57
121-3	1.06	1.06 ± 15.0%	1.00
121-8	0.62	0.65 ± 7.9%	1.05
125-8	0.88	0.84 ± 8.3%	0.95
130-8	0.77	0.89 ± 7.0%	1.16
143-8	2.57	2.86 ± 2.8%	0.90
145-3	2.36	1.95 ± 3.5%	0.83
146-8	2.36	1.85 ± 9.5%	0.78
151-3	4.71	4.01 ± 1.5%	0.85
152-3	3.06	2.91 ± 3.1%	0.95
212-7	0.93	0.94 ± 8.7%	1.01
229-2	1.06	1.22 ± 7.2%	1.06
244-2	4.71	4.47 ± 2.0%	0.95
247-7	0.62	0.32 ± 24.0%	0.52
366-8	6.53	4.02 ± 9.9%	0.62
368-2	3.27	1.80 ± 5.1%	0.55

(Continued)

TABLE 8(A) (Continued)

Sample Number	Spike Added (Dpm/Sample) (1)	Spike Observed (Dpm/Sample) (2)	Spike Observed ÷ Spike Added
399-3	6.53	4.87 ± 3.8%	0.75
415-3	5.89	5.80 ± 2.4%	0.98
416-2	9.14	8.51 ± 1.9%	0.93
416-3	1.63	1.57 ± 4.1%	0.96
418-2	1.63	1.50 ± 3.9%	0.92
447-7	11.83	10.70 ± 2.5%	0.90
447-8	4.90	5.14 ± 7.2%	1.05
469-3	3.27	3.17 ± 2.4%	0.97
475-3	6.53	5.80 ± 2.2%	0.89
477-3	0.99	0.89 ± 12.0%	0.91
483-2	8.17	6.44 ± 2.6%	0.79 (3)
483-3	2.60	2.38 ± 3.3%	0.92 (3)
493-7	0.65	0.40 ± 11.0%	0.62 (3)
494-3	3.27	3.13 ± 2.6%	0.96 (3)
507-7	3.27	2.66 ± 3.9%	0.81

(1) Values corrected for loss due to natural decay of the plutonium spike up to the time of the analysis.

(2) ± Coefficient of variation expressed as a percentage.

(3) Sample thawed after spike was added.

TABLE 8(B)

PU 236 MEASUREMENTS FOR UNSPIKED SAMPLES

The following samples were not spiked with Plutonium 236 but the laboratory reported a value significantly different from background.

Sample Number	Pu 236 Observed (Dpm/Sample)
322-2	0.08 ± 36.0%
322-3	0.11 ± 19.0%
323-2	0.22 ± 21.0%
324-3	0.07 ± 23.0%
325-2	0.04 ± 44.0%
330-2	0.07 ± 50.0%
334-2	0.57 ± 11.0%
337-3	0.07 ± 23.0%
345-2	0.06 ± 48.0%
361-2	2.28 ± 12.0%
379-2	0.10 ± 25.0%
388-2	0.12 ± 28.0%
389-2	0.12 ± 23.0%
403-3	0.15 ± 11.0%

TABLE 9(A)

PU 238 QUALITY ASSURANCE RESULTS FOR SPIKED SAMPLES*

Sample Number	Spike Added (Dpm/Sample) (1)	Spike Observed (Dpm/Sample) (2)	Spike Observed ÷ Spike Added
112-2	2.42	2.01 ± 4.7%	0.83
112-3	2.42	2.18 ± 4.4%	0.90
117-3	0.54	0.49 ± 9.3%	0.91 (3)
117-8	1.21	0.90 ± 25.0%	0.74
120-8	1.21	1.28 ± 13.0%	1.06
121-3	6.06	5.08 ± 8.2%	0.84
121-8	1.52	1.22 ± 6.2%	0.80
125-8	2.42	2.07 ± 7.6%	0.86
130-8	2.42	2.17 ± 6.3%	0.90
138-8	0.41	0.70 ± 18.0%	1.71 (3)
143-8	6.06	5.33 ± 3.2%	0.88
145-3	1.21	1.10 ± 5.8%	0.91
146-8	1.21	1.45 ± 15.0%	1.20
151-3	4.00	3.23 ± 4.7%	0.81
152-3	0.61	0.58 ± 8.1%	0.95
200-7	1.76	1.35 ± 22.0%	0.77
229-2	1.52	1.40 ± 9.4%	0.92
244-2	0.61	0.68 ± 6.5%	1.11
247-7	4.00	0.36 ± 28.0%	0.09
366-8	4.44	4.19 ± 10.0%	0.94
375-2	2.22	2.05 ± 4.1%	0.92
390-3	1.12	1.02 ± 10.0%	0.91
399-3	4.44	3.94 ± 4.8%	0.89
415-3	2.97	2.63 ± 4.7%	0.89

(Continued)

TABLE 9(A) (Continued)

Sample Number	Spike Added (Dpm/Sample)	Spike Observed (Dpm/Sample)	Spike Observed ÷ Spike Added
416-2	6.22	5.42 ± 3.3%	0.87
416-3	0.67	0.61 ± 9.3%	0.91
447-8	4.00	3.76 ± 9.8%	0.94
469-3	1.78	1.62 ± 4.6%	0.91
477-2	7.77	5.96 ± 3.4%	0.77
477-3	1.10	1.42 ± 11.0%	1.29
483-2	5.55	5.25 ± 4.2%	0.95 (4)
483-3	2.22	1.18 ± 6.2%	0.53 (4)
491-2	2.22	1.41 ± 20.0%	0.64 (4)
494-2	0.45	0.39 ± 12.0%	0.87 (4)
503-3	2.22	2.35 ± 6.2%	1.06 (4)
506-7	4.44	3.76 ± 5.7%	0.85 (4)

(1) Values corrected for loss due to natural decay of the plutonium up to the time of the analysis.

(2) ± Coefficient of variation expressed as a percentage.

(3) Tissue sample halves separated after the spike was added at NERC-LV, so the quantity of the spike was in question. Spike was a nitric acid solution.

(4) Sample thawed after spike was added.

*See Figure 3 for Statistical Summary

TABLE 9(B)

PU 238 MEASUREMENTS FOR UNSPIKED SAMPLES

The following samples were not spiked with Plutonium 238 but the laboratory reported a value significantly different from background for Pu 238.

Sample Number	Pu 238 Observed (Dpm/Sample)	Pu 239+240 Observed (Dpm/Sample)
106-2	0.09 ± 25.0%	1.24 ± 4.9%
180-2	0.14 ± 19.0%	2.66 ± 4.1%
181-2	0.28 ± 25.0%	0.84 ± 13.0%
189-2	0.32 ± 18.0%	3.07 ± 5.8%
196-2	0.09 ± 25.0%	1.03 ± 6.8%
206-2	0.08 ± 19.0%	1.72 ± 3.8%
212-7	0.26 ± 19.0%	5.50 ± 5.0%
228-2	0.07 ± 23.0%	1.04 ± 23.0%
255-2	0.40 ± 19.0%	5.04 ± 6.0%
258-2	0.08 ± 26.0%	1.67 ± 4.3%
262-2	0.52 ± 26.0%	2.25 ± 12.0%
297-2	0.13 ± 19.0%	2.60 ± 3.8%
318-2	0.12 ± 27.0%	5.32 ± 6.1%
320-2	0.46 ± 21.0%	2.22 ± 11.0%
321-2	0.18 ± 25.0%	3.60 ± 6.9%
324-2	0.10 ± 25.0%	1.36 ± 5.3%
325-3	0.11 ± 23.0%	0.22 ± 17.0%
344-2	0.28 ± 9.9%	5.51 ± 2.9%
347-3	0.13 ± 20.0%	2.14 ± 3.6%
349-2	0.10 ± 21.0%	2.08 ± 3.7%
350-2	0.12 ± 20.0%	1.27 ± 5.0%
351-2	0.12 ± 24.0%	7.97 ± 4.5%

TABLE 9(B) (Continued)

Sample Number	Pu 238 Observed (Dpm/Sample)	Pu 239+240 Observed (Dpm/Sample)
354-2	0.12 ± 16.0%	0.91 ± 5.4%
374-2	0.11 ± 20.0%	3.49 ± 3.4%
381-2	0.20 ± 15.0%	6.73 ± 2.6%
385-2	0.19 ± 14.0%	4.51 ± 3.1%
386-2	0.10 ± 22.0%	3.50 ± 3.4%
389-2	0.13 ± 20.0%	2.35 ± 4.0%
395-2	0.10 ± 26.0%	2.73 ± 4.1%
403-3	0.11 ± 16.0%	0.29 ± 11.0%
404-2	0.12 ± 22.0%	3.65 ± 3.5%
405-2	0.16 ± 25.0%	2.92 ± 6.8%
413-2	0.19 ± 13.0%	3.15 ± 3.7%
414-3	0.13 ± 20.0%	0.42 ± 11.0%
439-2	0.14 ± 24.0%	3.76 ± 3.9%
446-2	0.11 ± 16.0%	1.81 ± 4.5%
454-2	0.20 ± 14.0%	3.61 ± 3.7%
455-2	0.14 ± 16.0%	2.20 ± 4.6%
456-2	0.12 ± 30.0%	3.05 ± 7.2%
468-2	0.19 ± 20.0%	1.49 ± 5.8%
469-2	0.09 ± 19.0%	1.41 ± 5.0%
476-2	0.09 ± 19.0%	2.09 ± 4.1%
476-3	0.24 ± 12.0%	0.17 ± 17.0%
496-2	0.11 ± 19.0%	6.68 ± 3.0%
496-3	0.05 ± 26.0%	0.17 ± 13.0%
497-2	0.14 ± 21.0%	3.46 ± 4.6%
498-7	0.06 ± 25.0%	1.27 ± 5.1%

Some non-quality assurance samples also thawed by accident or during shipment. The fact that thawing did not seem to affect the accuracy of the quality assurance samples reassured us that such accidental thawing was not detrimental to the accuracy of the plutonium determinations in general.

One plutonium 238 sample, (247-7) showed only a 9% recovery of spike. The reason for the low recovery is most likely due to a processing error at step 4.1.8 of the chemical separation and purification procedure. A processing error at step 4.1.8 would result in non-equilibration of the Pu 238 spike and the Pu 242 tracer used to yield the sample. This one observation represents such an obvious outlier that it has been omitted from the summary of quality assurance statistics, (see Figure 3).

The standard deviations shown in Tables 8 and 9 are the relative errors reported by MCL for individual samples. They are based on standard calculations for count data and give some indication of the reliability of individual values with regard to the counting statistics only. See Figures 2 and 3 for a general picture of the overall accuracy of the plutonium measurements as determined from the quality assurance data for tissues spiked with plutonium 236 and plutonium 238. These figures show the relative frequencies of the occurrence of various degrees of accuracy in these measurements of Pu 236 and Pu 238. With the exception of the single aberrant observation previously mentioned (247-7), all reported measurements of these isotopes came out with an accuracy ratio (i.e. spike observed ÷ spike added) of more than 0.50 and less than 1.75.

The MCL reported no plutonium measurement unless the APHA counter showed a dpm value significantly different from background (for that isotope). They reported Pu 236 values significantly different from background for all the

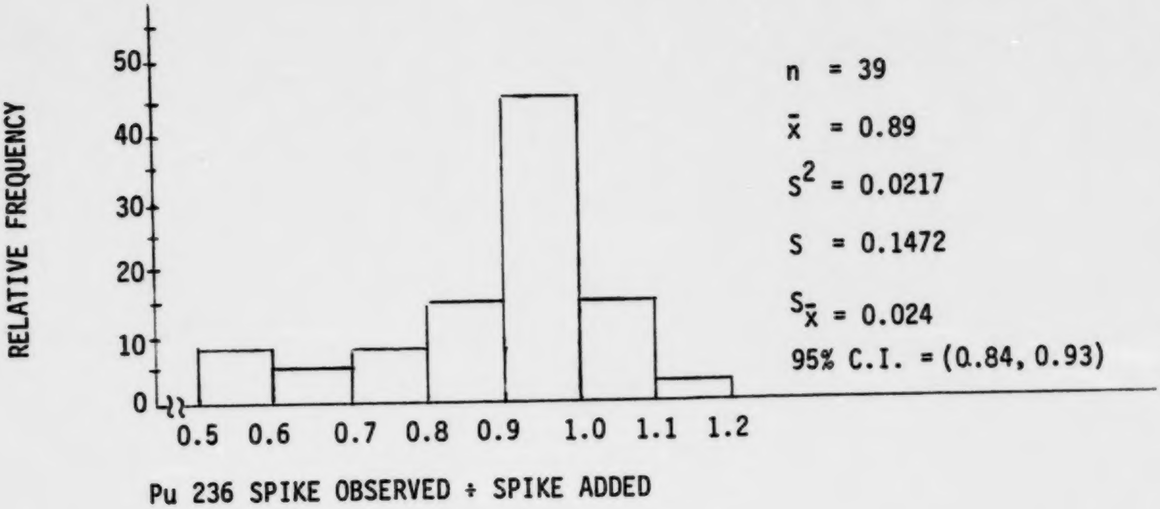


Figure 2. Distribution of Pu 236 Spike Observed ÷ Spike Added (See Table 8.A.)

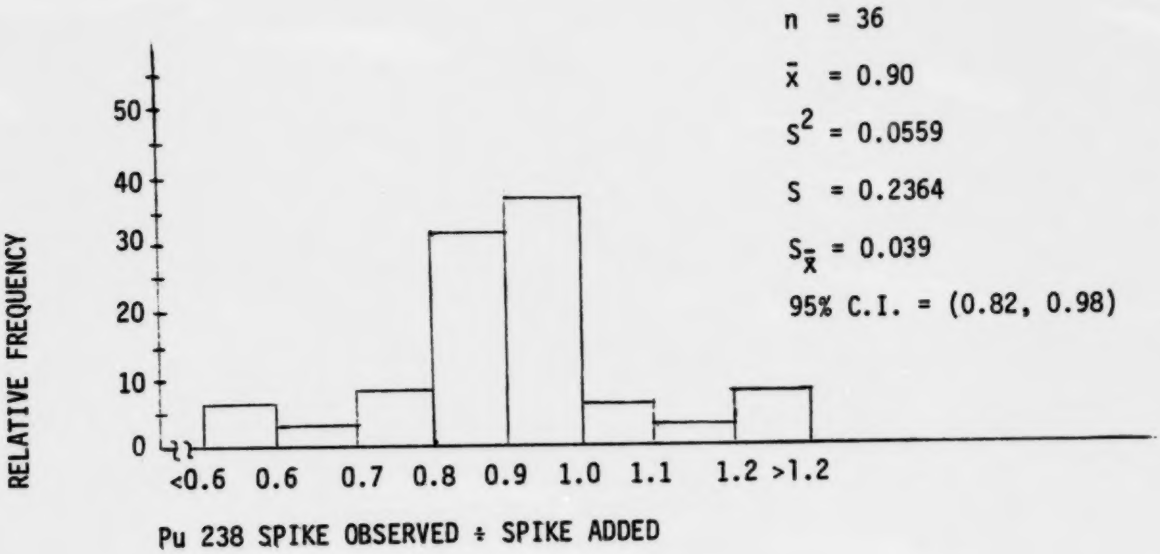


Figure 3. Distribution of Pu 238 Spike Observed ÷ Spike Added (See Table 9.A.)

39 samples spiked with Pu 236 and for 14 samples which had not been spiked with Pu 236; and they reported Pu 238 values significantly different from background for all the 36 samples spiked with Pu 238 and for 47 samples which had not been spiked with Pu 238.

Pu 236 is quite unlikely to occur in these tissues except from intentional spiking, or possibly from laboratory contamination. It has a short half-life (2.85 years), and very little is found in global fallout. On the other hand, Pu 238 has a half-life of 86 years and it does appear in global fallout at a level of about five percent of the combined activity of Pu 239+240 (Hardy,1973).

Table 8.B shows the Pu 236 activity levels reported by MCL for samples which had not been spiked with Pu 236. These reported activity levels were generally low (less than 0.25 dpm/sample except for sample 361-2 which was reported as 2.28 dpm/sample and sample 334-2 which was reported as 0.57 dpm/sample). The 14 false positive Pu 236 readings represent only 1.4% of the study samples which is probably not unreasonable, given their low values.

Table 9.B shows the Pu 238 activity levels reported by MCL for samples which had not been spiked with Pu 238. The last column of this table shows the reported activity levels of Pu 239+240. For each sample, the level of Pu 238 may be compared with the level of Pu 239+240; in a rough sense, 5% of the Pu 239+240 could be considered to be "expected" value for Pu 238, although the variation would be expected to be larger than for the spiked samples. In fact, upon calculating this percentage for each sample, the median value of Pu 238 as a percent of Pu 239+240 is 5.5%. The only extreme outlier is sample 476-3, for which the count of Pu 238 is greater than that for Pu 239+240, though both counts are small. About 23% of these values are greater than 10%, but most of these are based on low values of Pu 239+240 count.

For both plutonium 236 and plutonium 238, the average recovery fraction was 0.90 with 95% confidence limits on the true mean recovery fraction of about 0.85 - 0.95. However, there was a fair amount of variability for individual values. This variability is due to the aggregate effect of several different influences. One component of variability is caused by the various analytical errors which are naturally present in any complex laboratory procedure. This is probably best characterized by the distribution of values above the ratio 1.0 in Figure 2. Another major component is the presumed differential loss of spike from sample to sample due to various accidents in handling. This has a tendency to both spread out the distribution in the downward direction and to shift the mean value downward from 1.0. These two effects probably are the only ones influencing the distribution of the ratios in Figure 2, since, because of its short half-life (2.85 years), Pu 236 is not normally found in the environment. Plutonium 238, on the other hand, is present in the environment at approximately 5% of the plutonium 239 plus plutonium 240 levels, and that effect could account for the somewhat different shape of the ratio distribution curve for plutonium 238 (Figure 3) as compared with that for plutonium 236 (Figure 2).

Split Samples

The quality assurance samples that were spiked with plutonium 239 sometimes also contained measurable quantities of Pu 239 and Pu 240 which came from global fallout. Therefore, we did a study of the quantity and homogeneity of the fallout plutonium in pairs of split samples from the same individual. Tables 10 and 11 show results of analyses of unspiked split samples. The UCMC staff split the liver samples and submitted them to the MCL analytical laboratory as blind duplicate samples. They sent both right and left lungs from a few individuals to determine the variation between the two sides.

TABLE 10

COMPARISON OF PU 239 + PU 240 CONCENTRATION MEASUREMENTS BETWEEN PAIRS OF SPLIT LIVER SAMPLES

SAMPLE NUMBER	PU 239+240 CONCENTRATION FROM APHA (DPM/KG)(2)	PU 239+240 CONCENTRATION FROM M/S (DPM/KG)(2)	PU 240/239 ATOM RATIO(2)
143-2	1.20 ± 8%	1.55 ± 6%	0.22 ± 13%
143-7	0.68 ± 22%	--(1)	--
150-2	1.61 ± 5%	1.82 ± 2%	0.20 ± 3%
150-7	1.54 ± 8%	1.66 ± 10%	0.18 ± 20%
187-2	1.54 ± 13%	1.79 ± 2%	0.17 ± 5%
187-7	2.46 ± 11%	2.07 ± 1%	0.20 ± 3%
190-2	4.38 ± 7%	4.12 ± 2%	0.18 ± 4%
190-7	4.07 ± 7%	3.97 ± 1%	0.17 ± 1%
191-2	2.37 ± 11%	2.31 ± 1%	0.17 ± 1%
191-7	2.69 ± 14%	2.91 ± 1%	0.21 ± 2%
199-2	0.81 ± 14%	--	--
199-7	1.68 ± 8%	1.60 ± 5%	0.19 ± 11%
203-2	0.86 ± 18%	--	--
203-7	0.96 ± 13%	--	--
225-2	2.49 ± 5%	2.63 ± 1%	0.17 ± 2%
225-7	2.87 ± 9%	2.74 ± 1%	0.18 ± 2%

(Continued)

TABLE 10 (Continued)

SAMPLE NUMBER	PU 239+240 CONCENTRATION FROM APHA (DPM/KG)(2)	PU 239+240 CONCENTRATION FROM M/S (DPM/KG)(2)	PU 240/239 ATOM RATIO(2)
229-2	2.46 ± 11%	2.62 ± 2%	0.17 ± 4%
229-7	2.18 ± 9%	2.30 ± 5%	0.21 ± 9%
234-2	2.58 ± 6%	3.04 ± 2%	0.20 ± 3%
234-7	2.28 ± 9%	--	--
244-2	1.73 ± 6%	1.73 ± 1%	0.18 ± 3%
244-7	1.56 ± 6%	2.03 ± 2.4%	0.26 ± 4%
247-2	1.90 ± 16%	--	--
247-7	2.35 ± 10%	--	--
253-2	--	0.58 ± 4%	0.20 ± 7%
253-7	--	0.37 ± 8%	0.22 ± 15%
258-2	2.20 ± 4%	2.38 ± 2%	0.23 ± 4%
258-7	1.98 ± 8%	--	--
281-2	1.70 ± 8%	--	--
281-7	1.27 ± 9%	1.40 ± 3%	0.22 ± 6%
329-2	1.18 ± 18%	--	--
329-7	1.68 ± 10%	1.55 ± 3%	0.20 ± 6%
336-2	0.64 ± 8%	--	--
336-7	1.03 ± 15%	1.11 ± 3%	0.19 ± 6%
367-2	2.83 ± 5%	3.11 ± 7%	0.20 ± 13%
367-7	3.45 ± 5%	3.70 ± 7%	0.22 ± 9%

(Continued)

TABLE 10 (Continued)

SAMPLE NUMBER	PU 239+240 CONCENTRATION FROM APHA (DPM/KG)(2)	PU 239+240 CONCENTRATION FROM M/S (DPM/KG)(2)	PU 240/239 ATOM RATIO(2)
416-2	2.36 ± 5%	--	--
416-7	2.31 ± 5%	2.44 ± 2%	0.19 ± 4%
447-2	1.06 ± 10%	1.20 ± 2%	0.19 ± 4%
447-7	0.98 ± 10%	1.10 ± 2%	0.18 ± 5%
498-2 (3)	3.48 ± 9%	3.20 ± 3%	0.17 ± 4%
498-7 (3)	2.38 ± 5%	2.35 ± 1%	0.17 ± 3%

(1) -- Indicates that no measurement was reported.

(2) ± Coefficient of variation expressed as a percentage.

(3) Tissue thawed at MCL.

TABLE 11

COMPARISON OF PU 239+240 CONCENTRATION MEASUREMENTS BETWEEN LEFT AND RIGHT LUNG OF THE SAME INDIVIDUALS

SAMPLE NUMBER	PU 239 + 240 CONCENTRATION FROM APHA (DPM/KG) (2)	PU 239 + 240 CONCENTRATION FROM M/S (DPM/KG) (2)	PU 240/239 ATOM RATIO(2)
130-3	0.54 ± 22%	0.80 ± 8%	0.13 ± 19%
130-8	0.96 ± 15%	0.93 ± 4%	0.13 ± 11%
132-3	-- (1)	0.61 ± 5%	0.09 ± 12%
132-8	0.89 ± 23%	0.81 ± 6%	0.14 ± 7%
151-3	0.46 ± 16%	--	--
151-8	0.29 ± 12%	0.32 ± 3%	0.09 ± 8%
166-3	2.57 ± 16%	--	--
166-8	1.07 ± 20%	1.12 ± 3%	0.20 ± 6%
187-3	0.44 ± 21%	0.52 ± 8%	0.15 ± 11%
187-8	0.32 ± 20%	0.40 ± 3%	0.13 ± 7%
188-3	--	0.43 ± 4%	0.11 ± 12%
188-8	--	0.41 ± 8%	0.12 ± 18%
190-3	--	0.19 ± 3%	0.10 ± 9%
190-8	--	0.19 ± 4%	0.11 ± 9%
214-3	--	1.37 ± 2%	0.22 ± 4%
214-8	--	0.33 ± 2%	0.11 ± 6%
219-3	--	0.55 ± 11%	0.18 ± 20%
219-8	--	0.62 ± 5%	0.11 ± 14%

(Continued)

TABLE 11 (Continued)

SAMPLE NUMBER	PU 239 + 240 CONCENTRATION FROM APHA (DPM/KG)(2)	PU 239 + 240 CONCENTRATION FROM M/S (DPM/KG) (2)	PU 240/239 ATOM RATIO (2)
228-3	-- (1)	0.39 ± 11%	0.14 ± 8%
228-8	--	0.16 ± 6%	0.20 ± 10%
233-3	0.39 ± 27%	0.44 ± 6%	0.13 ± 11%
233-8	0.39 ± 24%	--	--
234-3	--	0.61 ± 8%	0.20 ± 16%
234-8	--	0.31 ± 19%	0.21 ± 22%
248-3	--	0.65 ± 8%	0.17 ± 19%
248-8	--	0.28 ± 4%	0.11 ± 13%
301-3	--	0.45 ± 9%	0.23 ± 14%
301-8	0.34 ± 26%	0.16 ± 11%	0.18 ± 25%
339-3	0.23 ± 19%	--	--
339-8	0.24 ± 24%	0.21 ± 5%	0.11 ± 9%
340-3	--	0.44 ± 3%	0.19 ± 7%
340-8	0.41 ± 13%	0.47 ± 4%	0.14 ± 9%
420-3	0.62 ± 26%	--	--
420-8	0.66 ± 27%	--	--
439-3	0.81 ± 6%	0.85 ± 2%	0.18 ± 6%
439-8	0.22 ± 21%	--	--

(1) -- Indicates that no measurement was reported.

(2) ± Coefficient of variation expressed as a percentage.

Paired Split Liver Measurements of Activity

Table 10 shows a series of paired measurements by APHA and/or MS for split liver samples, for a series of individuals. The plutonium activity measurements in dpm/kg of wet tissue and the ratios of Pu 240/239, together with the coefficients of variation expressed in percentage, as determined from counting statistics, are shown for both parts of each pair of split liver samples. This allows comparison between pairs of measurements made blindly at different times by the same method on split liver samples.

By either method of counting, APHA or MS, a pooled estimate of the standard deviation of a single measurment is on the order of 0.25 dpm/kg. This amount of variation is to be expected with only two observations per individual at this level of activity (on the order of 2 dpm/kg). A pooled estimate of the coefficient of variation is on the order of 10-15%.

Paired Right and Left Lung Measurements of Activity

Table 11 shows similar data for right and left lung pairs. The activity levels vary by as much as a factor of 3 between right and left lungs from the same individual but are generally on order of magnitude less than liver activities.

The plutonium isotope ratios (240/239) for the split liver samples, shown in Table 10, are around 0.20 and the average coefficient of variation for this measure is on the order of 5-10%. Mass spectrometric analysis of the Pu 240/Pu 239 isotope ratios in split liver samples indicate that this ratio is essentially the same in both halves of the liver. There is more variation between the right and left lungs.

Spikes with Plutonium 239

Table 12 and 13 show results from the quality assurance samples that were spiked with plutonium 239. Most of the samples were spiked with soluble plutonium (i.e., 2M HNO_3 solutions). Samples 111-7, 132-2 and 178-7 were spiked with highly refractory plutonium oxide particles to verify that all forms of plutonium were being dissolved by the chemical processing being used (Sill,1974). The fallout component for the samples reported in Table 12 was determined by analyzing a portion of the original unspiked samples and normalizing for weight difference. The quality assurance data derived from using the Pu 239 spike is consistent with the data derived from the Pu 236 and Pu 238 spikes.

Figures 4 and 5 show histograms and summary statistics for the Pu 239 spike recovery ratio data shown in Tables 12 and 13. For both liver and lungs, the mean recovery ratio for Pu 239 is slightly higher than for the Pu 236 and Pu 238 spikes. The amount of variability in recovery ratio between samples in the liver Pu 239 spiked samples data is comparable to that seen in the Pu 236 and Pu 238 spiked samples data, but the variability in the lung Pu 239 recovery ratio seems somewhat less than in the Pu 236 and Pu 238 spiked lung samples.

The three samples which were spiked with Pu 239 refractory particles and were considered acceptable (samples 111-7, 132-2 and 178-7) are shown in Table 12 with a note (2); the percentage of recovery for two of them was comparable with the recovery in samples that were spiked with a plutonium solution; the third, sample 132-2, was reported as "no plutonium detected," while the expected activity was 1.87 dpm.

Analysis of Residues

To find out whether the chemical procedures were recovering all the plutonium present in the ashed residues, forty consecutive samples were selected

TABLE 12

PU 239 SPIKED LIVER SAMPLES

			ACTIVITY		
SAMPLE NUMBER	BACKGROUND (FROM PAIRED SAMPLE) (DPM/SMPL)	SPIKE ADDED (DPM/SMPL)	EXPECTED (DPM/SMPL)	OBSERVED	OBSERVED÷EXPECTED
111-7	-- (1)	4.47(2)	4.47	3.74	0.83
132-2	0.38	1.49(2)	1.87	--	--
178-7	0.33	1.49(2)	1.82	1.75	0.96
200-7	0.79	12.21	13.00	12.0	0.92
212-7	2.34	3.91	6.25	5.50	0.88
368-2	0.93	2.22	3.15	2.22	0.71
375-2	1.35	2.22	3.57	3.48	0.97
418-2	1.39	0.66	2.05	1.86	0.91
491-2	0.92	4.42	5.34	5.75	1.08
493-7	1.03	1.10	2.13	2.16	1.01
494-2	0.69	0.44	1.13	1.37	1.21
495-2	1.49	2.20	3.69	3.76	1.02
496-2	2.26	4.44	6.70	6.68	1.00
497-2	2.08	1.10	3.18	3.46	1.09
500-2	2.71	6.67	9.38	7.71	0.82
506-7	0.59	8.89	9.48	8.73	0.92
507-7	0.84	6.67	7.51	6.19	0.82

(1) -- Reported as "No Plutonium Detected"

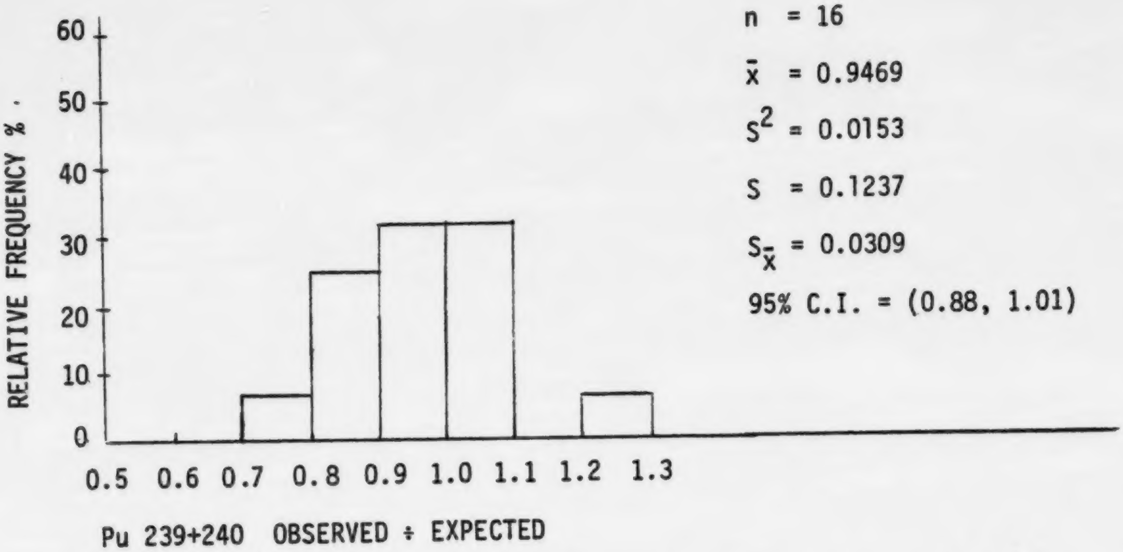
(2) Spiked with soil containing refractory plutonium oxide particles

TABLE 13

PU 239 SPIKED LUNG SAMPLES

SAMPLE NUMBER	BACKGROUND (FROM PAIRED SAMPLES) (DPM/SMPL)	SPIKE ADDED (DPM/SMPL)	EXPECTED ACTIVITY SPIKE + BACKGROUND (DPM/SMPL)	OBSERVED ACTIVITY (DPM/SMPL)	OBSERVED÷ EXPECTED
117-8	--(1)	2.44	2.44	2.38	0.98
118-8	0.30	4.88	5.18	4.87	0.94
119-8	--	4.88	4.88	4.57	0.94
375-3	--	0.44	0.44	0.46	1.05
384-3	0.12	1.56	1.68	1.60	0.95
390-3	--	2.22	2.22	2.19	0.99
391-3	0.21	0.66	0.87	0.92	1.06
475-3	0.11	4.44	4.55	3.88	0.85
491-8	0.16	3.32	3.48	3.44	0.99
494-3	--	4.44	4.44	4.17	0.94
503-3	--	2.22	2.22	2.26	1.02

(1) -- Reported as "No Plutonium Detected"



n = 16

$\bar{x}$ = 0.9469

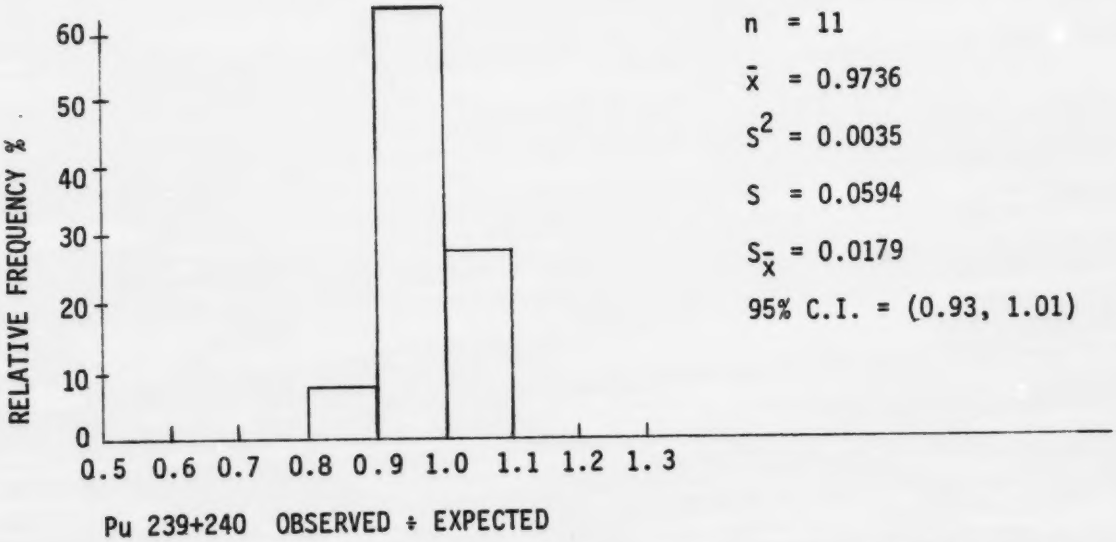
S^2 = 0.0153

S = 0.1237

$S_{\bar{x}}$ = 0.0309

95% C.I. = (0.88, 1.01)

Figure 4. Distribution of Pu 239+240 Observed ÷ Expected for Spiked Liver Samples



n = 11

$\bar{x}$ = 0.9736

S^2 = 0.0035

S = 0.0594

$S_{\bar{x}}$ = 0.0179

95% C.I. = (0.93, 1.01)

Figure 5. Distribution of Pu 239+240 Observed ÷ Expected for Spiked Lung Samples

for additional processing. For these forty samples, the filter papers and any remaining residue from the final filtering (step 4.1.15 in Step-by-step Procedures For Analysis) were subjected to an exhaustive HF/$HCLO_4$ dissolution at $90^{o}C$. The entire resultant solution was then treated as a separate sample and processed as described in steps 4.2.1 through 4.4.10 in the section on laboratory analysis, (Appendix H).

Table 14 shows the results of the chemical procedure check. In 85% of the residues, no plutonium was detected. Out of the 40 samples, 13 had originally been reported as "no plutonium detected"; and in all of these cases there was no plutonium detected in the residue. In the remaining 27 where plutonium was originally detected in the sample, six had a detectable amount of plutonium in the residue.

These results indicate that the chemical procedures used usually recovered nearly all of the plutonium that was present in the tissues. Thus we conclude that the recovery of an added inorganic spike is the same as the recovery of plutonium organically bound in the tissue. The few cases of discrepancies described above, the occasional low chemical yields, and the finding of plutonium in the residues of a few samples, are most probably indicative of technician errors in chemical processing of those samples, and not of systematic problems inherent in the chemical separation procedure itself.

Comparison of APHA with MS Values

The APHA values were, on the average, 4 percent lower than the MS values, and the correlation between them was r = 0.92. On the whole, the MS and APHA values were as close together as would be expected from the uncertainties involved. Occasional marked deviations probably resulted from errors in processing, not from any systematic error problem.

TABLE 14

ANALYSIS OF RESIDUES
PU 239+240 QUALITY ASSURANCE PROGRAM

SAMPLE NUMBER	SAMPLE PU 239+240 ACTIVITY (DPM/SMPL)	RESIDUE PU 239+240 ACTIVITY (DPM/SMPL)	RESIDUE EXPRESSED AS % OF SAMPLE
366-2	2.78	-- (1)	-
366-3	-- (1)	--	-
366-8	--	--	-
367-2	2.18	--	-
367-3	--	--	-
367-7	1.49	--	-
368-2	2.22	--	-
368-3	--	--	-
368-7	0.99	--	-
369-2	2.56	--	-
369-3	0.13	--	-
370-2	--	--	-
370-3	1.03	--	-
370-7	--	--	-
371-2	1.64	--	-
371-3	--	--	-
372-2	0.43	--	-
372-3	--	--	-
373-2	4.32	0.11	2.5%
373-3	0.59	--	-
374-2	3.49	0.13	3.7%
374-3	--	--	-

(Continued)

TABLE 14 (Continued)

SAMPLE NUMBER	SAMPLE PU 239+240 ACTIVITY (DPM/SMPL)	RESIDUE PU 239+240 ACTIVITY (DPM/SMPL)	RESIDUE EXPRESSED AS % OF SAMPLE
375-2	3.48	--	-
375-3	0.46	--	-
375-7	1.31	--	-
375-8	--	--	-
376-2	1.25	--	-
376-3	--	--	-
377-2	1.53	0.29	18.6%
377-3	0.15	--	-
378-2	0.41	0.17	41.5%
378-3	0.19	0.02	10.5%
379-2	0.80	--	-
379-3	--	--	-
380-2	0.52	--	-
380-3	--	--	-
381-2	6.73	--	-
381-3	0.19	0.07	36.8%
382-2	0.63	--	-
382-3	--	--	-

(1) -- Reported as "No Plutonium Detected"

The Quality Assurance data, and Analysis of Residues described above, indicate how rarely such processing problems actually did occur.

Possible Systematic Error

During the pathological examination of tissues at autopsy, the organs are removed from the body and usually sliced in such a way that blood and/or other fluid that had been in the tissue, seeps out of the tissue and is washed away. After death, (especially if tissue was frozen and thawed) the cell membranes become permeable; so that intracellular fluid as well as extra-cellular fluid may be drained out. We were concerned to find out how much plutonium might be lost systematically in this way. Therefore, from one liver (case #375) the UCMC staff collected about 100 ml of this tissue fluid, froze it, and sent it to MCL for plutonium determination in the usual way. This specimen (375-9) which weighed 97.7 grams showed 0.05 dpm of plutonium 239+240 by mass spectrometry with Pu 240/239 isotope ratio of 0.22 ± 0.06. This is to be compared to the findings in liver sample 375-7; this sample weighed 470.5 grams and showed 1.31 dpm of Pu 239+240 by APHA, or 1.22 dpm by MS, with a Pu 240/239 ratio of 0.19 ± 0.03. The whole liver from which this fluid drained weighed 1200 grams when removed from the body.

The above data indicate that when the liver loses about 10% of its weight in fluid seepage,as much as 1.5% of its plutonium may be lost. We do not know exactly how much tissue fluid may have drained from each tissue sample, but in those cases where the pathologist indicated they had given us the whole organ, we have some indication from the observed discrepancies between the weights recorded by the pathologist (usually soon after removing the organs from the body) and the weights of the samples as weighed by the UCMC staff.

THE PROBLEMS OF COUNTS NEAR BACKGROUND

Every two weeks throughout the period of laboratory measurement, MCL ran a 5000 minute count of background for each plutonium energy region on each spectrometer. Typical background levels were 0.004 counts per minute.

As mentioned in the section of Laboratory Analysis under Alpha Spectroscopy, the various counting instruments varied as to their sensitivity, and the count times varied according to laboratory exigencies. In addition, some of the plutonium samples were electroplated under less than ideal conditions. Non-ideal electroplating (e.g., coplating of trace quantities of iron and other metals not completely removed because of processing errors)of the plutonium resulted in degradation of the energy spectrum measured by the alpha spectrometers. The net result of all of these variability factors is that on some days, with some samples, the detectable level of Pu 239+240 in dpm per sample was very low, and on other days it was relatively high. The MCL originally reported the data on the first 822 APHA Pu 239+240 level measurements in a handwritten preliminary report. Among these were 333 "upper limit" values for the APHA measurements where the counts were statistically determined to be not significantly different from background. (See Alpha Spectroscopy, under Methods, Section 2.)

Figure 6 shows a histogram of these 333 "upper limit" alpha spectroscopy values. Over half of them fall between 0.1 and 0.3 dpm per sample and 3/4 of them are below 0.5 dpm per sample, but a few were relatively high.

Whenever possible, determinations resulting in "upper limit" values were rerun through the whole chemical separation process using another aliquot and, if indicated, a longer counting time. There could be three possible reasons for an "upper limit" value: either 1) the amount of plutonium in the sample was too small to be measured above the detection limits of the alpha spectrometers or 2) the chemical separation gave a low yield of the Pu 242 tracer or 3) an incomplete chemical separation had degraded the alpha spectrum and masked a measurable amount of plutonium.

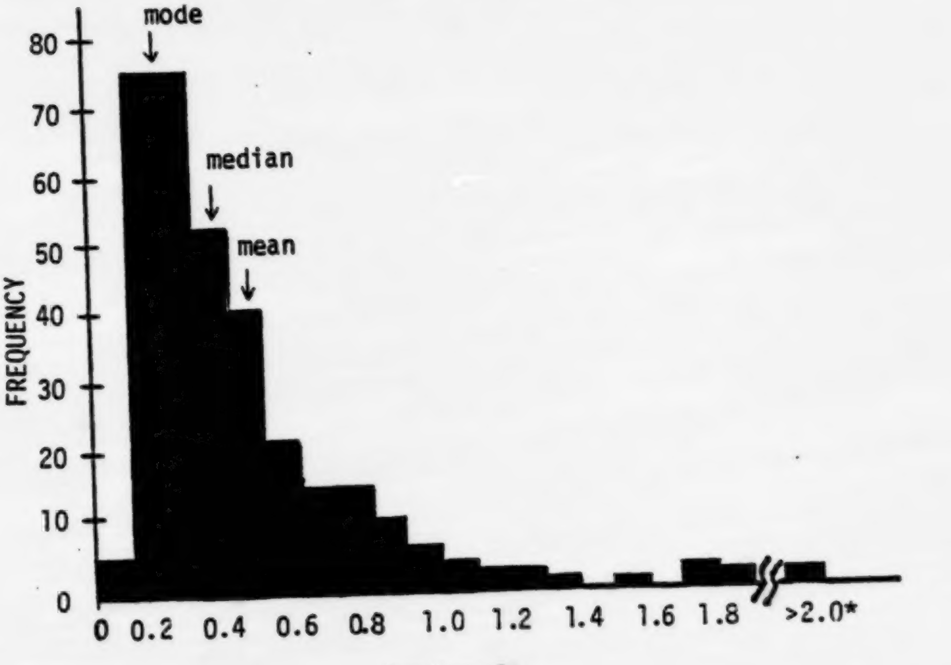
The decision to make a second APHA determination was made on the basis of the counting statistics and tracer yield of the first determination, and it was made by the MCL staff who did not know whether any given tissue sample was from a resident near Rocky Flats, or far away, or whether it might have been a quality control sample. The accuracy of the determinations in general is thus truly reflected by the accuracy of the spiked and paired samples discussed under Quality Assurance in Section 3.

If the second APHA determination resulted in a measurement which was statistically different from background (for the instrument and counting time involved) then this second APHA measurement was reported by MCL as the valid measurement for that tissue sample, regardless of whether it was higher or lower than the unofficially reported "upper limit" value. One would expect that generally the "valid" measurements would be lower than the "upper limit" values of the first determinations.

Up until November 1979, the decision to make a rerun was based only on counting statistics, tracer yield, and availability of an additional aliquot; starting in November 1979, the unavailability of additional funds and pressure of time precluded reruns for approximately the last 25% of the determinations.

Coplating of iron and other trace metals that degrade alpha spectra do not affect mass spectrometer measurements. Therefore, it was possible to obtain valid mass spectrometric measurements on some samples that were reported as "No Plutonium Detected" by alpha spectrometry. Of the 348 lung samples reported as "No Plutonium Detected" from APHA, there were 158 which yielded a valid measurement by MS, and of the 45 liver samples reported as "No Plutonium Detected" from APHA, there were 24 which yielded a valid measurement by MS. In these cases, we used the MS value for the statistical analyses which follow. The mean difference between APHA and MS being only 4%, and the variance between individuals being comparatively very high, we considered it to be unnecessary to make a correction for the average difference.

The statistical analyses on burden data which follow were first done leaving out those cases where both the APHA and MS determinations were reported as "No Plutonium Detected." Subsequently, some of the analyses were repeated including these samples with the value of zero substitued. (Clearly, the actual values were probably slightly greater than zero.) We felt these two analyses would represent the extreme cases.



mode = 0.20 median = 0.32 mean = 0.43 *2.94, 3.27

Figure 6. "Upper Limit" Alpha Spectroscopy Values

CALCULATION OR SELECTION OF INDIVIDUAL VALUES

For any one individual, MCL often reported both valid APHA and valid MS activity levels for Pu 239+240 for that individual's liver and/or lung. In addition, for some individuals, we had more than one sample of liver and/or lung; these were used for the quality assurance program. For the data bank used for the multiple regressions and statistical analyses which follow, we selected or calculated a single set of plutonium values for the lung and liver of each of the 449 individuals in the Study Population Sample. (See Figure 1) This Study Population Sample omits all individuals who might have been occupationally exposed to weapons grade plutonium or who might have resided on the Western Slope, (i.e., Y or U in Column 6 or 7 of Table 3).

The Pu activity was left blank when MCL reported that the sample was lost in analysis, or that the Pu 242 tracer was zero, or that "No Plutonium was Detected" by both APHA and MS for all samples of liver (or of lung) submitted from that same individual.

For samples where the Pu 242 tracer yield was either zero or left blank (lost in analysis), we have no information at all about the plutonium 239+240 activity; and it is certainly appropriate to leave these values blank. However, the report "No Pu Detected" meant that the counts were statistically not significantly different from background; so that no value, not even zero, could be assigned for that tissue sample of that individual with any degree of certainty. Nevertheless, when for a given tissue sample (shown in Table 5) there was a substantial yield of Pu 242 tracer reported with blank values for Pu 239+240 activity it would be reasonable to assume that this sample did have a relatively low Pu 239+240 activity.

It was the judgment of the MCL staff that the APHA measurements for Pu 239+240 activity level would be more reliable than the MS measurements. Therefore, when MCL reported both a valid APHA level and a valid MS activity level, we used only the APHA measurement. However, if the APHA gave "No Pu Detected" and there was a valid MS measurement, we used it. Because the variance is comparatively great, we made no correction for the small systematic difference between the APHA and MS values which we observed when both gave valid measurements. (The APHA values, on the average, were 4 percent lower than the MS values, and the correlation between them was $r = 0.92$.)

In cases where we had more than one sample of liver from the same individual, and valid measurments of Pu 239+240 were reported on each, we calculated a weighted average value for the liver concentration based on the error terms, and used the total liver weight, as recorded at autopsy, to calculate the total liver burden.

However, in lung tissue the plutonium is more unevenly distributed than in liver as shown in Tables 10 and 11; and much of the plutonium in the lungs is deposited in the lymph nodes. For these reasons, for calculating the "lung burdens," we included only cases where the sample submitted included more than 90% of either the right or the left lung; and for these cases, we used the reported Pu 239+240 activity level for the sample as the "lung burden". "Lung Burden" thus means lung burden for about 90% (or more) of either the right or left lung, not the total for right and left lungs combined. In the 3 cases where we had valid APHA measurements on both right and left lungs, where both were more than 90% samples and neither one was spiked with Pu 239, we used the one which had the smallest percentage error term. In 2 of these 3 cases, the smaller of the two measurements was thus selected. In all 3 cases where we only had valid MS measurements for both lungs, the smaller of the two measurements was selected. In all of these cases, the lung burden value was below 0.4 dpm per lung. Using average values instead would have made no important difference.

At some hospitals, the weights of the lung specimens submitted to us were much more than the weights of the fresh lungs as measured at the time of autopsy. Such weight increases resulted from routinely adding fixative solution to the lungs for pathological studies.

The Pu 240/239 isotope ratios were obtained from MS only. When MCL reported isotope ratios for more than one sample of lung or of liver, the average ratio of the samples was calculated and utilized for the statistical analyses, provided none of these samples had been spiked with Pu 239+240.

RESIDENCE HISTORY BY SECTORS AND TIME

The original purpose of the study was to find out whether the tissue of people who had lived near to and downwind from the Rocky Flats Plutonium Weapons Plant had more plutonium than the tissues of people living farther away. Therefore, we transformed the data from Table 1, where the coordinates of each address were given in the Universal Transverse Mercator System (UTMS), by calculating for each address a new set of coordinates relative to the location of the center of the Rocky Flats Plant (the coordinates of which in the UTMS are North 44154, East 04826).

These new coordinates allowed us to calculate the direction and distance from Rocky Flats for each address,and to classify each address by direction according to 30° sectors (1 through 12), and by distance according to areas A,B,C,D, as shown in Figure 7. Table 15 shows these data for each residence period for each individual.

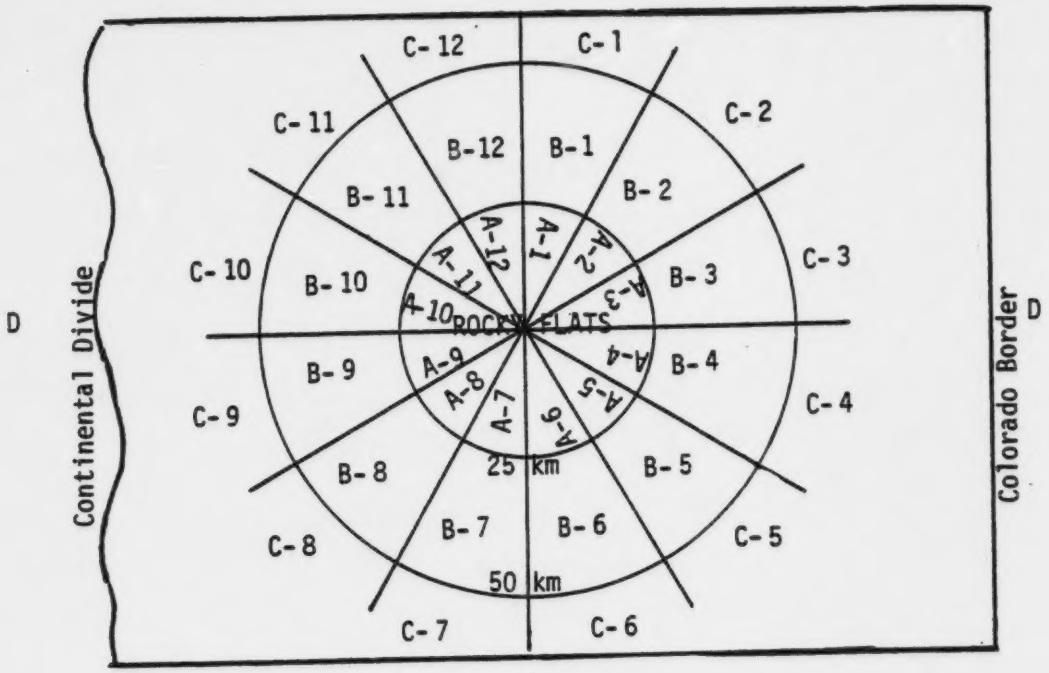

C-12
C-1
C-11
C-2
B-12
B-1
B-11
B-2
C-10
C-3
B-10
B-3
A-12
A-1
A-11
A-2
A-10
A-3
ROCKY FLATS
D
Continental Divide
Colorado Border
D
A-9
A-4
B-9
B-4
A-8
A-5
C-9
C-4
A-7
A-6
25 km
B-8
B-5
B-7
B-6
C-8
C-5
50 km
C-7
C-6

Figure 7. Sectors and Areas Relative to Rocky Flats (at center).

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
1	A- 5	55-75						
2	A- 6	70-75	A- 6	68-70				
3	A- 5	74-75	A- 6	69-74	A- 6	68-69	D- 3	-68
4	A- 6	73-75	B- 7	68-73				
5	A- 4	68-75						
6	A- 5	68-75						
7	A- 7	68-75						
8	A- 4	42-75						
9	A- 3	68-75						
10	A- 5	72-75	A- 5	68-72				
11	A- 5	68-75						
12	A- 3	74-75	A- 3	62-74				
13	A- 5	68-75						
14	B- 5	74-75	A- 5	44-74				
15	B- 6	59-75						
16	A- 5	73-75	A- 5	10-73				
17	A- 3	62-75						
18	A- 6	53-75						
19	A- 5	70-75	B- 5	68-70				
20	A- 5	72-75	A- 5	68-72				
21	A- 6	46-76						
22	C- 6	72-76	C- 6	68-72				
23	C- 6	72-76	C- 6	70-72	C- 6	68-70		
24	INTERVIEW NOT OBTAINABLE							
25	C- 6	68-76						
26	C- 9	37-75						
27	A- 3	72-76	D-11	59-72				
28	A- 5	64-76						
29	A- 6	68-76						
30	A- 5	51-76						
31	A- 6	50-76						
32	A- 5	48-76						
33	B- 5	55-76						
34	A- 7	56-76						
35	A- 5	52-76						
36	A- 6	75-76	A- 7	67-75				
37	A- 5	70-76	A- 5	20-70				
38	A- 5	56-76						
39	C- 6	68-76						
40	A- 5	50-76						

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
41	A- 5	61-76						
42	A- 5	51-76						
43	A- 6	72-76	C- 6	68-72				
44	B- 5	64-76						
45	C-12	73-76	A-12	9-73				
46	B- 5	70-76	B- 5	50-70				
47	B- 5	72-76	B- 5	70-72	D- 8	67-70		
48	B- 5	68-76						
49	B- 5	56-76						
50	B- 5	36-76						
51	B- 5	72-76	B- 5	63-72	D- 8	20-63		
52	A- 6	66-76						
53	A- 5	68-76						
54	A- 5	75-76	A- 7	50-75				
55	C- 6	68-76						
56	A- 5	49-76						
57	A- 6	60-76						
58	B- 7	62-76						
59	B- 5	68-76						
60	B- 5	70-76	B- 5	55-70				
61	A- 4	66-76	A- 5	-66				
62	A- 5	75-76	A- 4	56-75				
63	B- 5	68-76						
64	B- 5	68-76						
65	B- 5	72-76	B- 5	68-72				
66	B- 5	72-76	B- 5	60-72				
67	B- 5	71-76	B- 5	61-71				
68	C- 6	68-76						
69	B- 4	68-76						
70	B- 1	68-76						
71	B- 5	75-76	B- 5	74-75	B- 5	68-74		
72	B- 5	56-76						
73	A- 5	71-76	D- 3	12-71				
74	A- 5	73-76	C- 6	11-73				
75	B- 5	68-76						
76	B- 5	50-76						
77	A- 5	67-76						
78	A- 5	71-76	A- 5	52-71				
79	B- 4	64-76						
80	A- 6	72-76	A- 5	68-72				

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
81	A- 5	75-76			D- 3	8-71		
82	A- 5	72-76	A- 6	70-72	A- 4	45-70		
83	A- 5	66-76						
84	B- 5	68-76						
85	B- 5	68-76						
86	B- 5	68-76						
87	B- 5	40-76						
88	C- 6	68-76						
89	C- 6	45-76						
90	B- 5	76-76	B- 6	62-76	B- 5	45-62		
91	B- 5	52-76						
92	B- 5	59-76						
93	A- 5	55-76						
94	A- 7	75-76	A- 7	68-75				
95	B- 5	68-76						
96	A- 6	68-76						
97	B- 5	73-76	A- 4	71-73	B- 6	70-71	A- 5	68-70
98	A- 5	42-76						
99	B- 5	68-76						
100	A- 5	68-76						
101	B- 4	68-76						
102	C- 6	53-76						
103	C- 5	67-76	C- 5	63-67	C- 5	60-63	C- 5	57-60
104	C- 6	58-76						
105	A- 5	46-76						
106	A- 5	68-76						
107	B- 5	61-76	D-12	55-61				
108	A- 5	47-76						
109	A- 4	70-76	A-12	56-70				
110	A- 6	68-76						
111	A- 7	49-76						
112	A- 5	66-76	B- 5	51-66				
113	C- 6	52-76						
114	C- 6	53-76						
115	A- 4	60-76						
116	A- 5	75-76	B- 5	73-75	B- 5	68-73		
117	B- 5	68-76	A- 5	-68				
118	B- 7	68-76						
119	B- 5	54-76						
120	C- 6	10-76						

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
121	C- 6	68-76						
122	C- 6	68-76						
123	B- 5	68-76	A- 5	-68				
124	A- 5	58-76	D- 3	-58				
125	B- 5	68-76						
126	C- 6	35-76						
127	C- 6	56-76	D- 9	51-53				
128	C- 6	52-76						
129	C- 6	63-76						
130	B- 5	69-77						
131	A- 6	74-77	D- 9	68-74				
132	B- 5	68-77						
133	B- 6	76-77	D- 9	70-76	D- 9	51-70		
134	B- 5	75-77	B- 5	72-75	B- 5	68-72		
135	B- 6	68-77						
136	A- 5	68-77						
137	A- 5	71-77	D- 4	70-71	D- 9	68-70	A-12	63-68
138	C- 5	61-77	C- 6	9-61				
139	C- 5	56-77						
140	C- 5	64-77						
141	A- 4	70-77	B- 5	37-70				
142	A- 5	68-77						
143	A- 5	68-77						
144	A- 5	70-77	B- 5	60-70				
145	B- 6	68-77						
146	B- 5	59-77	B- 5	56-59				
147	A- 6	73-77	A- 5	63-73	A- 5	61-63		
148	B- 9	68-77						
149	C- 6	68-77						
150	B- 5	76-77	B- 5	68-76				
151	B- 5	69-77	D- 9	68-69				
152	A- 5	68-77						
153	A- 3	65-77						
154	A- 5	45-77						
155	B- 5	69-77	B- 5	57-69				
156	B- 5	68-77						
157	A- 5	68-77						
158	B- 6	63-77	B- 6	58-63	B- 6	56-58		
159	A- 5	58-77						
160	B- 6	61-77	D- 9	60-61	D- 6	47-60		

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
161	A- 7	35-77						
162	A- 4	71-77	A- 4	70-71	B- 5	59-70	B- 5	57-59
163	A- 7	68-77	A- 6	64-68	A- 7	56-64		
164	A- 6	68-77						
165	D- 4	73-77	A- 5	68-73	A- 5	-68		
166	A- 4	74-77	A- 5	71-74	C- 5	68-71		
167	A- 5	68-77	A- 5	15-68				
168	A- 5	68-77						
169	A- 5	68-77						
170	C- 6	34-77						
171	D-10	71-77	C-11	67-71	B- 5	33-67		
172	C- 6	48-77						
173	A- 5	56-77						
174	B- 5	42-77						
175	INTERVIEW NOT OBTAINABLE							
176	A- 5	68-77						
177	B- 5	56-77						
178	C- 5	74-77	D- 6	70-74	B- 4	70-70	C- 3	68-70
179	B- 5	56-77						
180	A- 5	60-77						
181	A- 4	68-77						
182	B- 5	68-77	B- 5	46-68				
183	B- 5	50-77						
184	A- 5	68-77						
185	B- 5	50-77						
186	C- 6	56-77						
187	B- 5	74-77	B- 5	45-74				
188	B- 6	56-77						
189	C- 6	72-77	C- 6	56-72				
190	A- 5	68-77						
191	B- 5	68-77						
192	B- 5	76-77	A- 5	73-76	A- 5	69-73	D- 2	39-69
193	A- 5	68-77						
194	C- 6	68-77	C- 6	45-68				
195	C- 6	65-77						
196	C- 6	40-77						
197	C- 6	56-77						
198	C- 6	50-77						
199	B- 5	71-77	A- 5	57-71				
200	B- 5	76-77	B- 5	50-76				

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
201	B- 5	68-77						
202	A- 5	69-77	A- 5	57-69				
203	B- 5	68-77						
204	B- 5	46-77						
205	B- 5	76-77	B- 5	75-76	B- 4	50-75		
206	C- 5	75-77	D- 9	40-75				
207	B- 5	56-77						
208	A- 7	71-77	A- 5	68-71	A- 5	63-68	C- 5	-63
209	A- 5	56-77						
210	A- 5	70-77	A- 4	69-70	B- 4	67-69	A- 5	-67
211	A- 5	72-77	C- 6	67-72	B- 5	56-67		
212	A-12	69-77	C- 6	54-69				
213	B- 5	67-77	B- 5	56-67				
214	B- 5	56-77						
215	A- 6	58-77	A- 6	52-58				
216	B- 5	73-77	D- 7	72-73	B- 5	51-72		
217	INTERVIEW NOT OBTAINABLE							
218	C- 6	56-77						
219	C- 4	69-77	D- 4	63-69	B- 5	61-63	C- 4	21-61
220	C- 6	56-77						
221	B- 5	56-77						
222	B- 5	72-77	B- 5	56-72				
223	A- 5	56-77						
224	A- 5	70-77	A- 5	55-70				
225	A- 6	59-77	B- 5	28-59				
226	B- 5	39-77						
227	C- 6	56-77						
228	B- 5	46-77						
229	A- 5	70-77	A- 5	56-70				
230	A- 5	67-77	A- 5	62-67	B- 5	56-62		
231	A- 5	56-77						
232	B- 5	67-77						
233	B- 5	61-77	B- 5	60-61	B- 5	50-60		
234	B- 5	56-77						
235	C- 6	19-77						
236	B- 6	66-77	B- 5	55-66				
237	C- 4	56-77						
238	C- 3	56-77						
239	B- 5	70-77	B- 5	67-70	B- 5	63-67	C- 5	61-63
240	B- 5	72-77	C- 6	67-72	B- 5	59-67	D- 1	40-59

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
241	B- 5	56-77						
242	A- 5	56-77						
243	A- 6	68-77	D- 3	12-68				
244	D- 5	56-77						
245	C-12	45-77						
246	INTERVIEW NOT OBTAINABLE							
247	B- 5	58-77						
248	B- 5	68-78	B- 5	42-68				
249	A- 5	74-78	A- 4	66-74	D- 3	50-66		
250	B- 6	60-77	B- 5	56-60				
251	A- 4	73-77	B- 5	72-73	B- 5	71-72	D- 4	49-71
252	A- 5	71-78	D- 8	45-71				
253	C- 6	48-78						
254	C- 5	34-78						
255	C- 6	40-78						
256	A-12	74-77	B- 3	70-74	B- 3	67-70	A- 6	65-67
257	C- 6	20-78						
258	C- 6	37-78						
259	C- 6	45-78						
260	A- 6	75-78	B- 5	45-75				
261	A- 5	62-78	B- 5	52-62				
262	A- 5	56-78						
263	A- 4	73-78	C- 1	72-73	A- 5	51-72		
264	A- 4	76-78	D- 9	74-76	A- 4	54-74		
265	A- 5	56-78						
266	C- 6	55-78						
267	C- 6	75-78	D- 8	26-75				
268	D- 4	45-78						
269	C- 6	70-78	D- 4	57-70				
270	C- 6	77-78	D- 6	60-77	D- 9	30-60		
271	C- 6	19-78						
272	C- 6	12-78						
273	C- 6	75-78	D- 3	47-75				
274	C- 6	44-78						
275	B- 5	68-78	B- 5	56-68				
276	B- 5	63-78	D-12	-63				
277	B- 5	61-78	D- 3	56-61				
278	C- 6	74-78	C- 6	63-74	D- 2	61-63	C-6	56-61
279	C- 6	77-78	D- 1	74-77				
280	C- 6	30-78						

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
281	C- 6	40-78						
282	B- 5	52-78						
283	B- 5	75-78	B- 5	73-75	B- 5	44-73		
284	B- 5	55-78						
285	C- 6	12-78						
286	B- 5	63-78	B- 4	53-63				
287	A- 5	55-78						
288	B- 5	73-78	B- 5	56-73				
289	A- 5	68-78	A- 5	43-68				
290	INTERVIEW NOT OBTAINABLE							
291	A- 5	41-78						
292	C- 6	56-78						
293	C- 6	66-78	C- 6	62-66	C- 5	56-62		
294	C- 6	72-78	A- 4	66-72	D- 2	63-66	C- 7	44-63
295	C- 6	44-78						
296	C- 6	47-78						
297	C- 6	61-78	D- 9	55-61	D- 3	50-55		
298	C- 6	42-78						
299	C- 6	57-78						
300	C- 5	42-78						
301	B- 5	56-78						
302	B- 5	71-78	B- 5	67-71	B- 5	63-67	B- 5	61-63
303	A- 7	73-78	A- 6	47-73				
304	A- 4	58-78	A- 4	56-58				
305	A- 5	70-78	A- 5	69-70	A- 5	51-69		
306	A-12	40-78						
307	B- 5	76-78	B- 5	46-76				
308	C- 6	69-78	D- 4	45-69				
309	C- 6	30-78						
310	C- 6	42-78						
311	C- 5	44-78						
312	C- 6	50-78						
313	C- 6	50-78						
314	C- 6	40-78						
315	C- 6	77-78	A- 5	50-77				
316	C- 6	24-78						
317	C- 6	58-78						
318	C- 7	76-78	C- 7	46-76				
319	C- 6	72-78	D- 3	62-72				
320	C- 6	62-78	D- 3	21-62				

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
321	A- 3	74-78	A- 4	70-74	D- 3	30-70		
322	A- 7	76-78	A- 7	54-76				
323	A- 5	77-78	A- 5	52-77				
324	A- 5	66-78	D-10	63-66	D- 7	50-63		
325	A- 5	70-78	A- 5	69-70	C- 6	68-69	A- 5	50-68
326	B- 5	71-78	B- 5	61-71	D- 5	-61		
327	B- 5	73-78	D- 3	50-73				
328	C- 7	55-78	C- 6	45-55				
329	C- 6	49-78						
330	C- 6	69-78	D- 4	64-69	D- 7	61-64		
331	D- 4	30-78						
332	D- 4	60-78	D- 4	25-60				
333	A- 5	76-78	B- 5	51-76				
334	C- 6	76-78	D- 3	45-76				
335	D- 5	64-78	D- 9	62-64	D- 2	57-62		
336	C- 6	46-78						
337	C- 6	77-78	C- 6	55-77				
338	B- 5	43-78						
339	B- 5	62-78	A- 5	21-62				
340	B- 5	56-78						
341	C- 6	71-78	C- 3	65-71	C- 6	35-65		
342	C- 6	46-78						
343	C- 6	45-78						
344	C- 6	53-78						
345	C- 6	40-78						
346	B- 4	47-78						
347	C- 6	56-78						
348	C- 6	77-78	D- 3	70-77	D- 3	32-70		
349	C- 6	44-78						
350	C- 6	48-78						
351	C- 6	11-78						
352	C- 6	58-78	D- 4	35-58				
353	C- 6	67-78	D- 8	43-67				
354	C- 6	58-78	B- 4	54-58				
355	C- 6	74-78	D- 3	4-74				
356	C- 6	40-78						
357	C- 4	40-78						
358	C- 6	61-78	D- 4	48-61				
359	C- 6	74-78	D- 8	63-74	D- 4	57-63		
360	C- 6	40-78						

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
361	C- 6	42-78						
362	B- 5	48-78						
363	B- 5	38-78						
364	A- 5	75-78	A- 5	70-75	C- 6	43-70		
365	B- 5	64-78	B- 5	62-64	D- 7	57-62		
366	A- 5	64-78	A- 5	46-64				
367	B- 5	56-78						
368	C- 6	73-78	D- 5	71-73	D- 8	49-71		
369	C- 6	45-78						
370	C- 6	76-78	D- 6	74-76	D- 4	64-74	D- 4	45-64
371	C- 6	40-78						
372	C- 6	63-78						
373	D- 8	45-78						
374	B- 5	59-78	B- 5	56-59				
375	A- 5	68-78	B- 5	66-68	D-12	65-66	A- 6	56-65
376	A- 5	77-78	B- 5	64-77	A- 5	50-64		
377	A- 5	66-78	A- 5	50-66				
378	B- 5	64-78	D- 1	60-64	D- 2	10-60		
379	B- 5	60-78	B- 5	58-60	B- 5	50-58		
380	C- 6	63-78	D- 2	60-63	C- 6	51-60		
381	C- 6	49-78						
382	C- 6	77-78	D- 4	9-77				
383	C- 6	58-78	D- 2	45-58				
384	B- 5	71-78	B- 5	51-71				
385	C- 6	45-78						
386	C- 7	48-78						
387	D- 4	45-78						
388	C- 6	51-78						
389	C- 6	23-78						
390	B- 5	75-78	B- 7	74-75	A- 6	73-74	D- 3	45-73
391	B- 5	70-78	B- 3	56-70				
392	A- 5	56-78						
393	A- 6	60-78	D- 9	12-60				
394	A- 5	69-78	A- 6	49-69				
395	A- 7	72-78	A- 7	62-72	A- 7	53-62		
396	A- 5	68-78	A- 5	60-68	A- 5	51-60		
397	A- 5	52-78						
398	A- 5	76-78	D- 3	69-76	D- 3	56-69		
399	A- 5	65-78	D- 3	57-65	D- 2	55-57		
400	B- 5	77-78	B- 5	72-77	B- 5	52-72		

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
401	A- 5	64-78	A- 4	55-64				
402	B- 5	46-78						
403	C- 3	74-78	C- 3	54-74				
404	B- 5	56-78						
405	B- 5	77-78	B- 5	75-77	D- 2	56-75		
406	A- 3	63-78	D- 9	59-63				
407	B- 5	56-78						
408	B- 6	72-78	A- 5	70-72	B- 5	69-70	D- 3	45-69
409	B- 5	66-78	A- 5	64-66	A- 5	60-64		
410	B- 5	75-78	B- 5	73-75	B- 4	71-73	B- 5	63-71
411	B- 5	75-78	A- 5	73-75	B- 5	68-73	B- 5	61-68
412	A- 4	57-78						
413	B- 5	66-78	D- 5	45-66				
414	B- 1	76-78	B- 1	74-76	A- 2	54-74		
415	B- 5	73-78	B- 5	67-73	B- 5	65-67	B- 5	50-65
416	B- 5	68-78	B- 5	56-68				
417	A- 5	56-78						
418	B- 5	74-78	B- 5	71-74	A- 5	56-71		
419	A- 6	75-78	A- 5	69-75	A- 5	63-69	A- 5	56-63
420	A- 6	74-79	A- 5	73-74	B- 5	62-73	C- 6	-62
421	B- 5	69-78	D- 9	53-69				
422	B- 5	76-78	B- 5	74-76	B- 5	56-74		
423	INTERVIEW NOT OBTAINABLE							
424	B- 5	56-78						
425	A- 7	76-79	A- 5	54-76				
426	B- 5	73-79	B- 5	63-73	B- 5	61-63	B- 5	59-61
427	B- 5	76-79	D- 4	56-76				
428	B- 5	58-79	D- 3	40-58				
429	B- 4	75-79	A- 4	73-75	B- 5	72-73	A- 5	53-72
430	C- 6	64-78	D- 4	49-64				
431	C- 6	64-78						
432	C- 6	3-78						
433	C- 6	91-78						
434	C- 6	66-78	D- 2	65-66	C- 6	55-65	D- 2	52-55
435	C- 6	70-78	C- 5	30-70				
436	C- 6	77-78	D- 4	60-77	C- 6	40-60		
437	C- 6	45-78						
438	C- 5	35-79						
439	A- 5	74-79	A- 5	73-74	B- 5	61-73	B- 5	45-61
440	B- 5	37-79						

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
441	A- 5	66-79	A- 5	59-66	A-12	58-59	D- 4	56-58
442	A- 3	72-79	D- 3	61-72				
443	B- 1	40-79						
444	B- 5	78-79	B- 5	56-78				
445	A- 6	72-79	D- 3	52-72				
446	A- 4	68-79	A- 4	66-68	A- 4	56-66		
447	B- 5	45-79						
448	A- 5	55-79						
449	C- 5	66-79	D- 4	17-66				
450	D- 4	10-79						
451	C- 6	45-79						
452	C- 6	65-79	D- 3	57-65				
453	A- 5	74-79	B- 5	71-74	B- 5	69-71	B- 4	66-69
454	A- 5	69-79	D- 1	18-69				
455	B- 5	58-79	A- 5	55-58				
456	A- 4	71-79	A- 5	65-71	D- 8	50-65		
457	C- 6	78-79	D- 9	38-78				
458	C- 7	45-79						
459	C- 6	74-79	D- 3	40-74				
460	D- 7	76-79	C- 6	73-76	D- 7	51-73		
461	C- 6	40-79						
462	C- 7	70-79	D- 3	32-70				
463	D- 8	45-79						
464	C- 6	77-79	D- 3	70-77	D- 3	65-70	D- 9	60-65
465	C- 6	46-78						
466	C- 5	38-78						
467	C- 6	72-78	D- 3	64-72				
468	B- 5	58-79	B- 5	52-58				
469	B- 5	76-79	B- 5	64-76	D- 4	-64		
470	A- 5	64-79	A- 4	33-64				
471	B- 5	59-79	A- 4	56-59				
472	A- 4	56-79						
473	B- 5	56-79						
474	B- 5	59-79	B- 5	56-59				
475	B- 5	73-79	B- 5	72-73	D- 3	45-72		
476	B- 5	68-79	S- 5	39-68				
477	A- 5	72-79	A- 5	56-72				
478	C- 6	42-79						
479	C- 6	46-79						
480	C- 6	37-79						

TABLE 15

CASE	MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE		NEXT MOST RECENT RESIDENCE	
	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD	AREA	PERIOD
481	C- 6	14-79						
482	C- 6	70-79	B- 5	65-70	D- 2	38-65		
483	C- 6	78-79	C- 6	73-78	B- 5	56-73		
484	C- 6	60-78	D- 9	58-60				
485	B- 5	64-79	A- 5	60-64	A- 3	56-60		
486	A- 4	77-79	A-12	71-77	D- 9	69-71	D- 3	56-69
487	A- 5	53-79						
488	D- 8	64-79	C- 5	57-64	D- 8	55-57		
489	B- 5	76-79	A- 4	70-76	B- 5	60-70	B- 5	-60
490	A- 5	78-79	C- 7	23-78				
491	B- 5	62-79	B- 5	50-62				
492	INTERVIEW NOT OBTAINABLE							
493	C- 1	40-79						
494	C- 6	45-79						
495	C- 6	53-79	C- 3	52-53	C- 6	45-52		
496	C- 6	73-79	D- 4	0-73				
497	C- 6	39-79						
498	C- 6	48-79						
499	C- 6	78-79	D- 9	62-78	D- 3	45-62		
500	C- 6	48-79						
501	C- 6	60-79	D- 3	54-60				
502	B- 5	43-79						
503	B- 5	56-79						
504	C- 7	56-79						
505	B- 5	74-79	A- 6	66-74	C- 4	64-66	A- 6	50-64
506	C- 3	38-79						
507	B- 4	75-79	D- 6	42-75				
508	B- 4	70-79	D- 8	56-70				
509	B- 6	76-79	B- 5	74-76	A- 6	71-74	D- 3	39-71
510	C- 6	77-79	D- 9	45-77				
511	C- 6	45-79						
512	C- 6	46-79						
513	C- 5	16-79						
514	C- 6	70-79	C- 6	50-70	C- 5	30-50		
515	C- 6	31-79						
516	C- 6	68-79	D- 9	63-68	C- 6	40-63		
517	C- 6	56-79						
518	B- 5	56-79						
519	A- 6	75-79	A- 6	74-75	A- 6	72-74	A- 5	67-72

The statistical analyses which follow are, unless otherwise stated, based upon the residence at which individuals lived during most of the last 5 years of their lives. We did also analyse the data with reference to two other time periods; 1) the 1968-70 period when leaking drums of cutting oil containing plutonium were being moved and the area was being paved, and 2) the time of the plutonium fire in September 1957. So far as we know, these two occurrences are the most likely sources of high levels of Pu air contamination occurring at Rocky Flats:

(1) Between January and June 1968, 3,570 old oil drums containing cutting oil contaminated with plutonium, many of which had been leaking, were being removed from the open air storage area at Rocky Flats and transported to building 774 for processing. Some of the drums leaked or ruptured during transportation, and high winds spread the plutonium. The S-8 air sampler at the east perimeter fence showed that the airborne radioactive contaminants were relatively high during 1968 and 1969, peaking to a monthly average of 0.75 dpm/m^3 in late 1968. During this period, weeds were burned and mechanized equipment was used on the area to cover the plutonium contaminated soil with fill material and asphalt; this work was completed in November 1969 (Seed, 1971).

(2) In September 1957, plutonium metal spontaneously ignited in a glovebox and several kilograms burned. Large amounts of smoke filled the room and the exhaust fans were turned on high speed to clear the smoke, which was plainly visible as it left the stack. The fire spread up the exhaust ducts to the exhaust filter plenum. Flammable filters soon caught fire destroying a major portion of the filtering system. This spread of fire was accompanied by an explosion in the exhaust duct. A 15 minute, high volume air sample taken downwind (south) during the fire indicated a concentration of about 8.8 dpm/m^3 of plutonium (Hammond, 1971).

Many measurements of soil plutonium concentration levels have been made in the area around the perimeter of the Rocky Flats Plant, starting with Martell in 1970. The most recent study was done by the Rockwell International Energy Systems Group of the Rocky Flats plant (Illsley, 1979). Their study showed that of 20 measurements made of soil samples 5 cm in depth from the offsite area 3 km due east of the center of the Rocky Flats plant itself, between Indiana Avenue and the Great Western Reservoir, there was one measurement as high as 7.56 dpm per gram, two measurements between 2.0 and 3.0 dpm/g, twelve between 1.0 and 2.0 dpm/g, and 5 less than 1.0. In the same study, 6 measurements were made in the offsite area 3 km due west from the center of the plant, between Route 93 and the western border of the plant. Of these, the highest concentration was 0.15 dpm/g. There were three measurements between 0.10 and 0.15 dpm/g, and there was one of 0.07 dpm/g and one of 0.05 dpm/g. The five "background values" measured in the same study in places around the state far from Rocky Flats were all in the range of 0.02 to 0.07 dpm/g. Thus it appears that the plutonium content of surface soil offsite east of the plant is about twenty times background, and at least ten times as high as it is west of the plant. The above measurements were all made on total soil samples taken down to 5 cm depth. For comparison, the State of Colorado permits unrestricted construction in areas where the plutonium concentration is 2.0 dpm/g or less.

The higher concentration of plutonium east of Rocky Flats is presumably due to the prevailing winds blowing from west to east. This presumption is further substantiated by the study of remote plutonium contamination from Rocky Flats done by measuring the Pu 240/Pu 239 ratios in soil samples collected in the Denver region during September and October 1972 (Krey, 1976b). This study found that at distances between 10 and 25 km from the plant, the highest contamination with weapons grade plutonium occurred in the easterly direction from the plant (0.72 ± 0.19 mCi/km^2) and the next highest contamination occurred in three locations 12 km to 25 km from the plant in the southeasterly direction (0.24 to 0.47 mCi/km^2); whereas there was no detectable weapons grade plutonium contamination in 5 samples taken 10 to 25 km from the plant in the southerly, westerly, northwesterly and northeasterly directions from the plant. On the basis of these data, we define east and southeast to be the "downwind directions from Rocky Flats" for the purposes of this study. This assumption agrees with observations of wind patterns around Rocky Flats (EPA, 1977).

Considering that the plutonium particles most likely to be resuspended from the soil and inhaled are probably the smaller particles of respirable size, the Jefferson County Health Department, working with the US Geological Survey, developed a method of measuring the plutonium concentration in soil particles of respirable size, i.e. less than 5 μm diameter, (Johnson, 1976). They reported 4 measurements of plutonium concentration in the respirable fraction of the surface soil in the area 3 to 4 km due east of the center of the plant, as follows: 59 dpm/g, 83 dpm/g, 120 dpm/g and 170 dpm/g. They had one measurement of "background" soil by this method, from a point 23 km south-southeast of Rocky Flats. This "control" sample had a plutonium concentration of only 0.45 dpm/g by the same method, suggesting an increase of about two orders of magnitude for the area east of the plant.

Measurement of the plutonium concentration in sediments at various levels in a core sample from the bottom of Standley Lake, which is 5 km from the center of the plant and 3 km southeast of the Great Western Reservoir, showed that the plutonium concentration increased rapidly from a concentration of about 0.1 dpm/g for sediment deposited during 1966, up to a peak of over 1.0 dpm/g for sediment deposited in 1969; and it has fallen off slowly and steadily since then to about 0.1 dpm/g for 1976 sediment (Hardy, 1978). These measurements confirm the peak concentration of plutonium in air in 1968, and are also consistent with the 1970 measurements of plutonium in soil in that area (Krey, 1970).

The releases from the plant have been decreasing in recent years according to US Department of Energy data. The highest known concentration of plutonium in air near Rocky Flats occurred during the 1957 fire, 4 pCi/m^3 (Hammond, 1971). (This equals 4x10^6 a Ci/m^3 or 8.8 dpm/m^3.) This relatively high level was probably of relatively short duration, as compared with the lower more sustained levels coming from the oil drum spill area during 1968-70. In 1969, measurements east of the plant reached a peak of 3.5x10^5 a Ci/m^3 or 0.77 dpm/m^3 (Seed, 1971). Between 1970 and 1978, measurements of plutonium concentration in air at Rocky Flats, by monitor Number 1(3) remained in the range of 10^3 to 10^4 a Ci/m^3; it was consistently about two orders of magnitude higher than similar measurements made in New York City by the same laboratory, and it was about 3 orders of magnitude higher than their measurements in uncontaminated areas such as Antaractica and Pt. Barrow, Alaska which remained in the range of 1 to 5 a Ci/m^3, (Toonkel, 1979 and Volchok, 1976).

In Figure 7, Area A includes any residence location 25 km or less away from Rocky Flats (North 44154, East 04826). Area B includes residence locations more than 25 km and less than or equal to 50 km away. Area C is the area outside of the 50 km circle but within Colorado, east of the Rocky Mountains;

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(3) At the eastern security fence which was ¼ km east of the oil drum spill area, and about 3/4 km west of the plant boundary up to 1974, when the plant area was enlarged to include the most contaminated areas.

and Area D includes all locations outside of eastern Colorado. The suffix number (1 through 12) indicates the direction according to 30^o sectors, starting with North and proceeding clockwise. Thus, Denver residences are mostly in sector 5, Golden in sector 7, and Boulder in sector 12. (Residence locations which fall exactly on a dividing line between sectors are included in the adjacent counterclockwise sector.)

Using the scheme shown in Figure 7, Table 16 (A,B, and C) and Figure 8 (A,B, C) show the geographic distribution, at different periods, of our 490 autopsied individuals who, so far as we know, had not been exposed to weapons grade plutonium except as a result of their environmental exposure in eastern Colorado. We call this group of 490, the "ANOE," an acronym for "Autopsied, Not Otherwise Exposed."

To get an idea of the representativeness of our "ANOE" sample, the geographic distributions shown in Table 16 (A,B, and C) and Figure 8 (A,B, and C) may be compared to the distribution of resident population around Rocky Flats shown in Figure 8.D. The data for Figure 8.D were derived from Figure AT-5 on pages 18 and 19 of the Summary Report on plutonium guidelines (EPA, 1977), and are presumably originally derived from the 1970 census. Thus, they would be most appropriately compared to Table 16.B and Figure 8.B which show the geographic distribution of our 490 "ANOE" in the period 1968-70.

The residence data show that, in general, our autopsy cases came from the heavily populated areas in and around Denver, Colorado Springs, and Pueblo, with scattered cases from all of Colorado. Relatively few (only 3) of them had resided at places within 10 km of Rocky Flats. This is because that area was very sparsely settled in those years. Thus, the data do not allow any conclusions about the plutonium burden in people living closer than 10 km to Rocky Flats.

TABLE 16 (A)

DISTRIBUTION OF CASES BY GEOGRAPHIC LOCATION IN 1957
Number (%) of Cases At This Location During 1957

Sector	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
AREA A		1 (0.3)	1 (0.3)	11 (3.0)	55 (15.0)	8 (2.2)	7 (1.9)					3 (0.6)	86 (23.5)
AREA B	1 (0.3)		1 (0.3)	4 (1.1)	82 (22.4)	2 (0.5)							90 (24.6)
AREA C	1 (0.3)		3 (0.8)	3 (0.8)	11 (3.0)	89 (24.3)	7 (1.9)		1 (0.3)			1 (0.3)	116 (31.7)
AREA D	2 (0.5)	6 (1.6)	27 (7.4)	19 (5.2)	3 (0.8)	1 (0.3)	1 (0.3)	7 (1.9)	6 (1.2)			2 (0.5)	74 (20.2)
TOTAL	4	7	32	37	151	100	15	7	7			6	366 Valid 124 Missing Addresses

TABLE 16 (B)

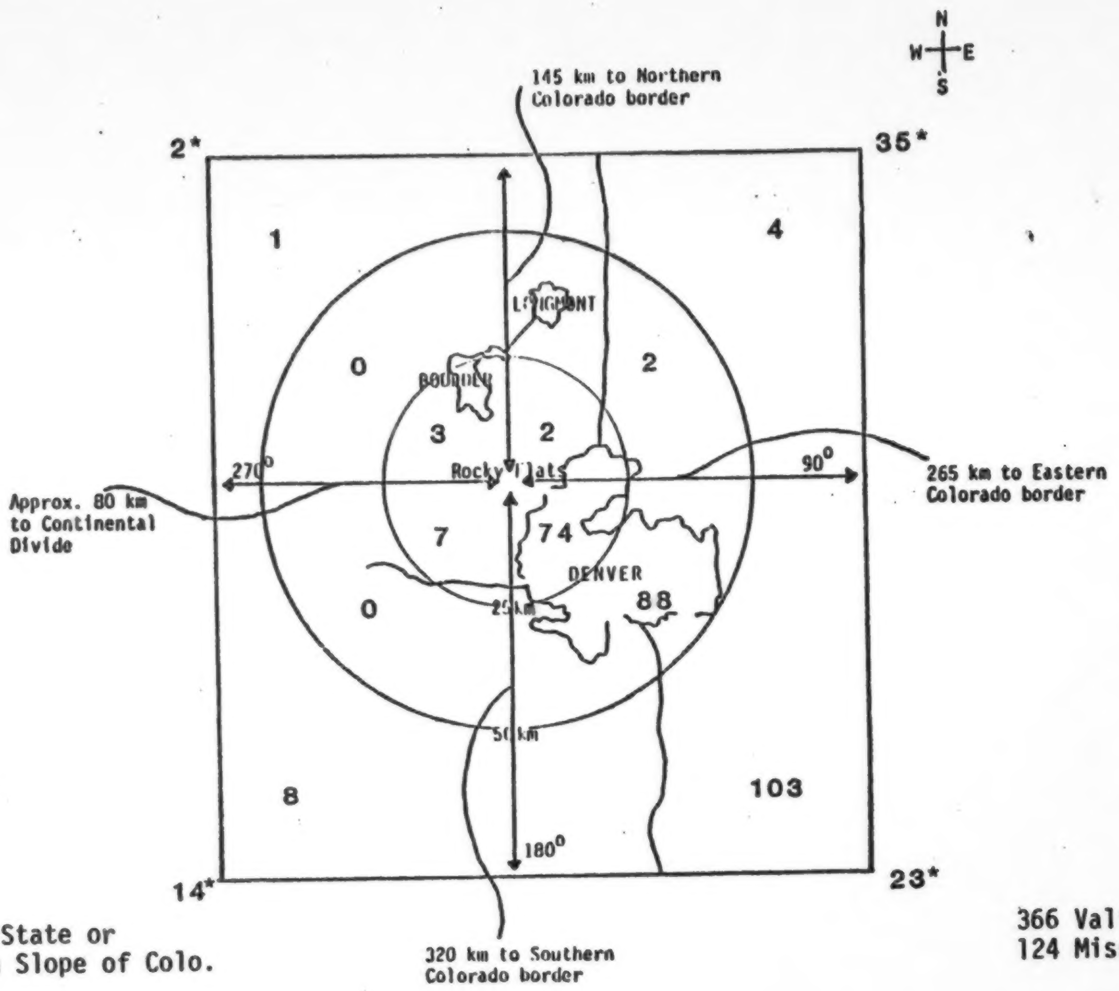
DISTRIBUTION OF CASES BY GEOGRAPHIC LOCATION 1968-1970
Number (%) of Cases At This Location During 1968-70

Sector	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
AREA A		1 (0.2)	5 (1.1)	14 (3.0)	82 (17.6)	15 (3.2)	10 (2.1)					3 (0.6)	130 (27.8)
AREA B	2 (0.4)		2 (0.4)	5 (1.1)	126 (27.0)	7 (1.5)	3 (0.6)		1 (0.2)				146 (31.3)
AREA C	1 (0.2)		5 (1.1)	2 (0.4)	13 (2.8)	111 (23.8)	6 (1.3)		1 (0.2)		1 (0.2)	1 (0.2)	141 (30.2)
AREA D		1 (0.2)	18 (3.9)	12 (2.6)	2 (0.4)	2 (0.4)		8 (1.7)	6 (1.3)		1 (0.2)		50 (10.7)
TOTAL	3	2	30	33	223	135	19	8	8		2	4	467 Valid 23 Missing Addresses

TABLE 16 (C)

DISTRIBUTION OF CASES BY GEOGRAPHIC LOCATION LAST 5 YEARS OF LIFE
Number (%) of Cases At This Location During Last 5 Years of Life

Sector	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
AREA A			8 (1.7)	17 (3.6)	91 (19.2)	23 (4.8)	12 (2.5)					4 (0.8)	155 (32.6)
AREA B	2 (0.4)			7 (1.5)	126 (26.5)	9 (1.9)	3 (0.6)		1 (0.2)				148 (31.2)
AREA C	1 (0.2)		3 (0.6)	3 (0.6)	12 (2.5)	123 (25.9)	7 (1.5)		1 (0.2)			2 (0.4)	152 (32.0)
AREA D			2 (0.4)	8 (1.7)	2 (0.4)	1 (0.2)		2 (0.4)	4 (0.8)	1 (0.2)			20 (4.2)
TOTAL	3		13	35	231	156	22	2	6	1		6	475 Valid 15 Missing Addresses

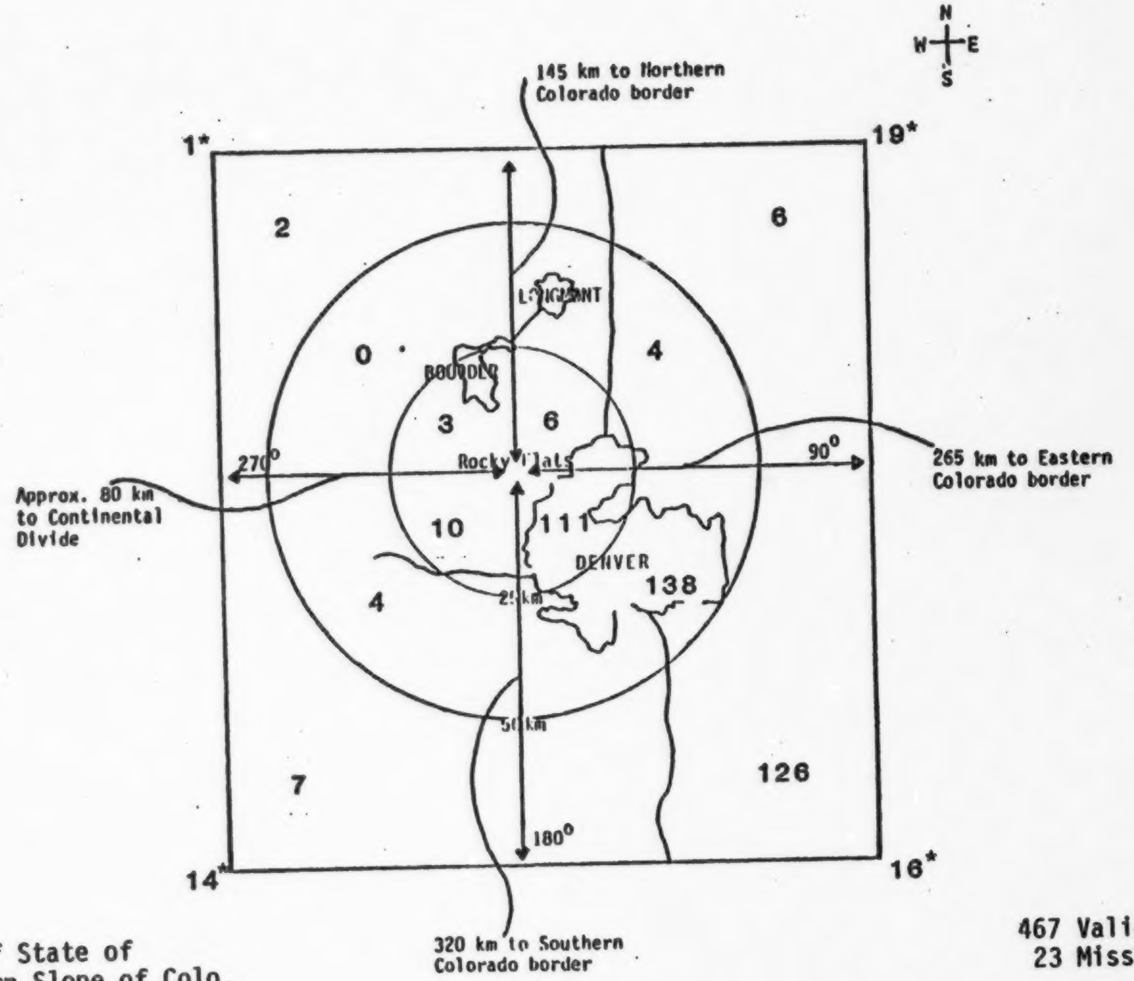

N
W
E
S
145 km to Northern Colorado border
2*
35*
1
4
LONGMONT
0
BOULDER
2
3
2
270°
Rocky Flats
90°
Approx. 80 km to Continental Divide
265 km to Eastern Colorado border
7
74
DENVER
0
25 km
88
50 km
8
103
180°
14*
23*
320 km to Southern Colorado border

*Out of State or
Western Slope of Colo.

366 Valid Cases
124 Missing Addresses

Figure 8 (A)

DISTRIBUTION OF CASES BY GEOGRAPHIC LOCATION DURING 1957

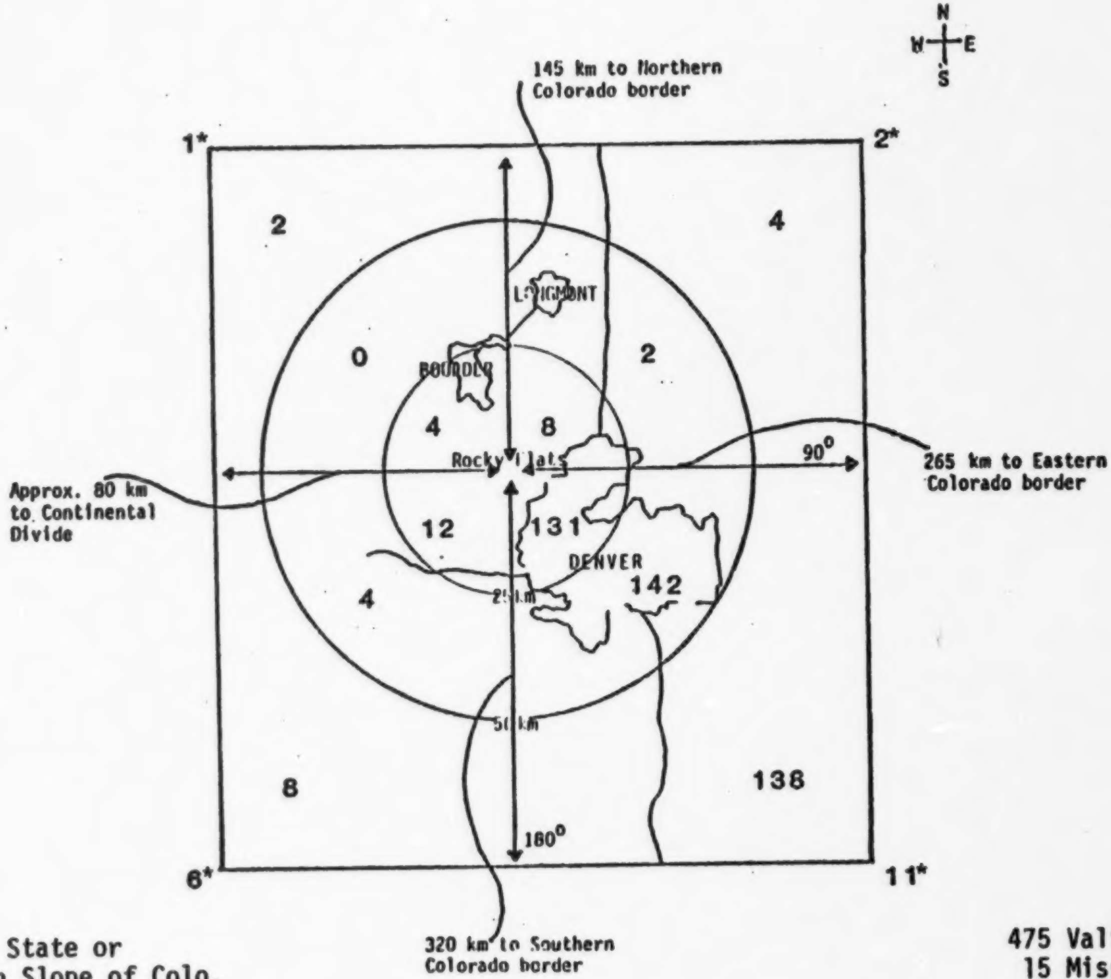

N
W
E
S
145 km to Northern Colorado border
1*
19*
2
6
LONGMONT
0
BOULDER
4
3
6
270°
Rocky Flats
90°
265 km to Eastern Colorado border
Approx. 80 km to Continental Divide
10
111
DENVER
138
4
25 km
50 km
7
126
180°
14*
16*
320 km to Southern Colorado border

*Out of State of
Western Slope of Colo.

467 Valid Cases
23 Missing Addressed

Figure 8 (B)

DISTRIBUTION OF CASES BY GEOGRAPHIC LOCATION DURING 1968-70

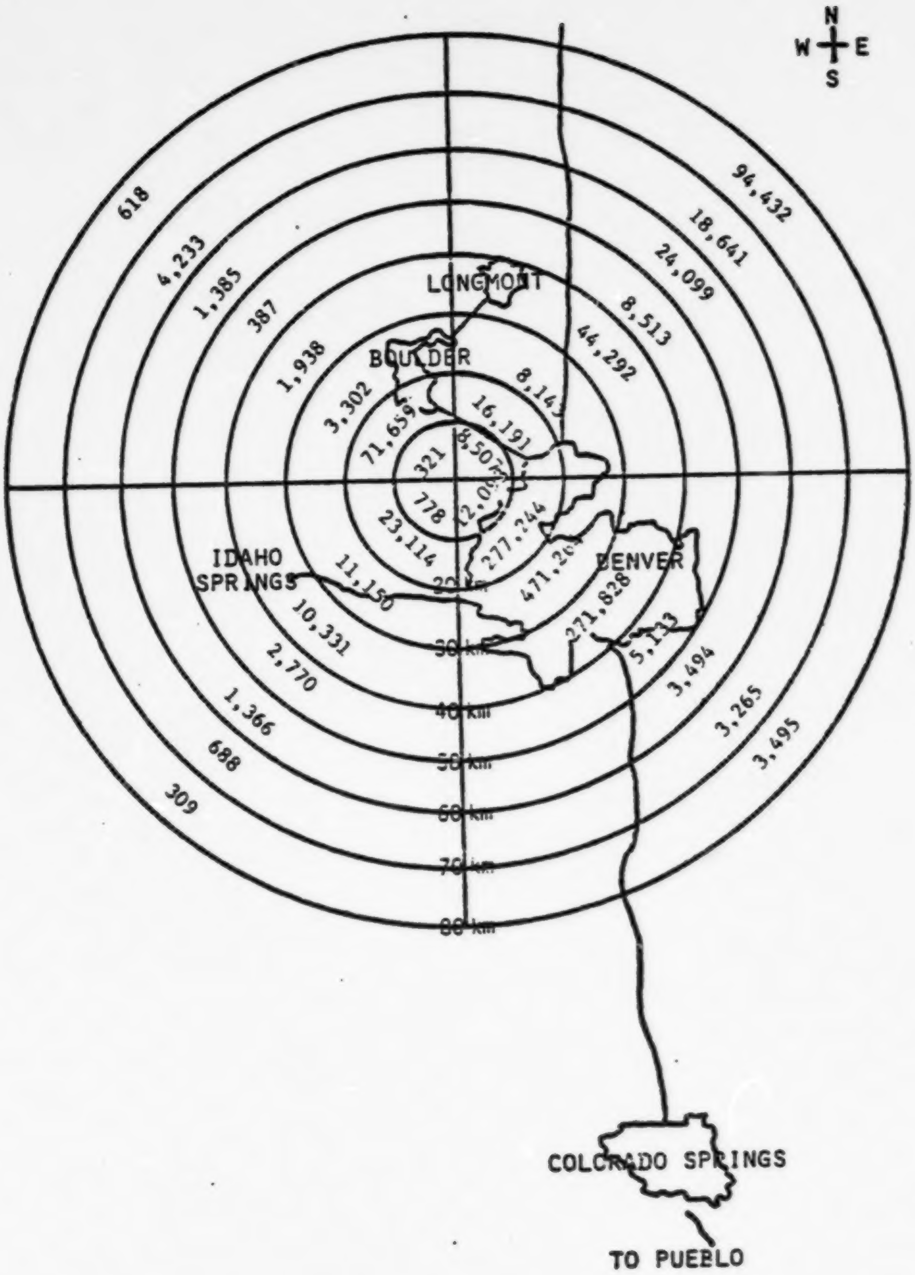

N
W
E
S
145 km to Northern Colorado border
1*
2*
6*
11*
2
4
0
2
4
8
12
131
4
142
8
138
LONGMONT
BOULDER
Rocky Flats
DENVER
25 km
50 km
90°
180°
Approx. 80 km to Continental Divide
265 km to Eastern Colorado border
320 km to Southern Colorado border

*Out of State or
Western Slope of Colo.

475 Valid Cases
15 Missing Addresses

Figure 8 (C)

DISTRIBUTION OF CASES BY GEOGRAPHIC LOCATION DURING LAST 5 YEARS OF LIFE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W
E
S
618
4,233
1,385
387
1,938
3,302
71,659
321
94,432
18,641
24,099
8,513
44,292
8,14
16,191
8,50
12,0
778
23,114
277,244
471,2
271,828
5,133
3,494
3,265
3,495
11,150
10,331
2,770
1,366
688
309
LONGMONT
BOULDER
DENVER
IDAHO SPRINGS
20 km
30 km
40 km
50 km
60 km
70 km
80 km
COLORADO SPRINGS
TO PUEBLO

Figure 8(D). Resident Population Around Rocky Flats (1970)

SECTION 4

STATISTICAL ANALYSES

In the following presentation, we first look at the distribution of pertinent demographic variables, then at the marginal distributions of plutonium determinations both alone and stratified on potential confounding variables, and finally, we report the results of various multivariate procedures, undertaken in order to investigate the possibility of trends after adjusting for potential confounding factors.

DESCRIPTIVE STATISTICS

Figures 9 and 10 show the distribution of the "ANOE" population by sex, age at death, and packyears of smoking history. As might be expected, we have an aged population with females slightly older than males, and the males were much heavier smokers. Almost two-thirds of the females were non-smokers.

Figure 11 shows the percentage of the 490 "ANOE" cases with a residence history that was known for n years or more before death. This graph, and the data on missing cases in Table 16, (A,B, and C) show that we have a residence history for 97% of the individuals during the last 5 years of life, for 95% during the 1968-70 period, and for 75% at the time of the 1957 fire.

Figure 12 shows the distribution of observed liver and lung burdens, separately by sex. In plotting the liver burdens, the relatively small fraction of cases reported as "No Pu Detected" have been included in the lowest group. However, because this fraction is large in the lung burden data, these cases reported as "No Pu Detected" have not been included in the lung burden plots.

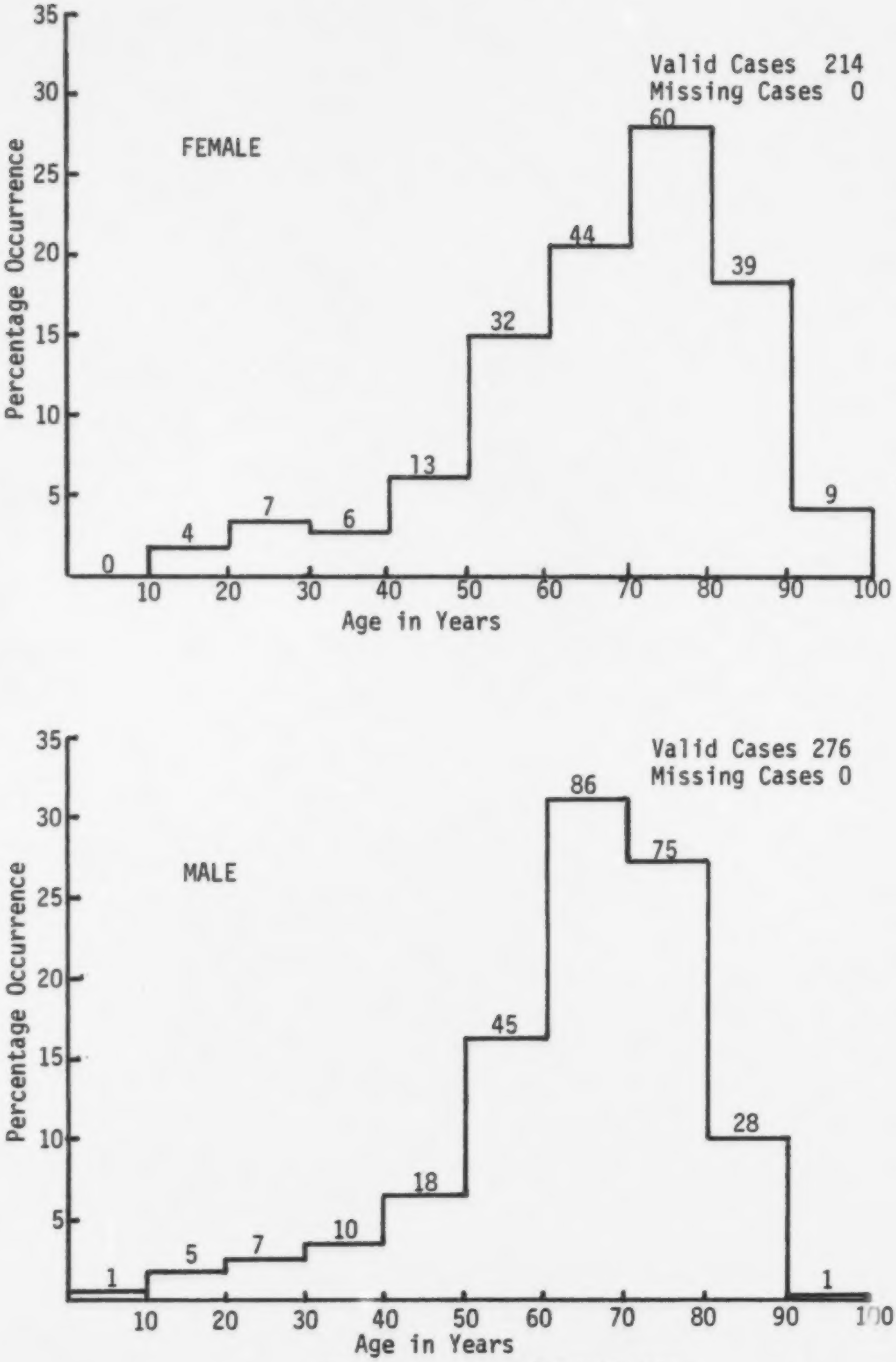


Figure 9 . Age Distribution

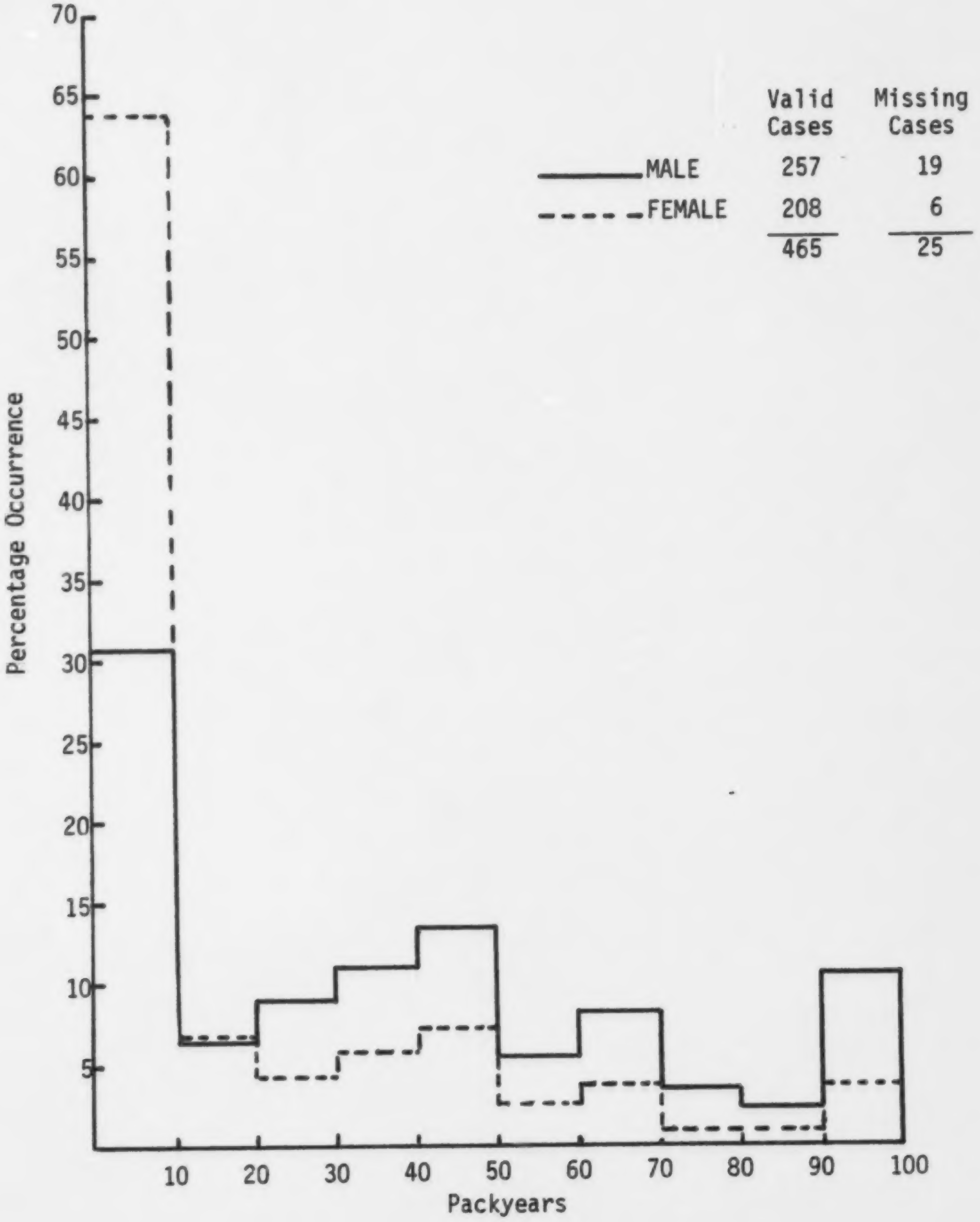


Figure 10. Packyears of Smoking

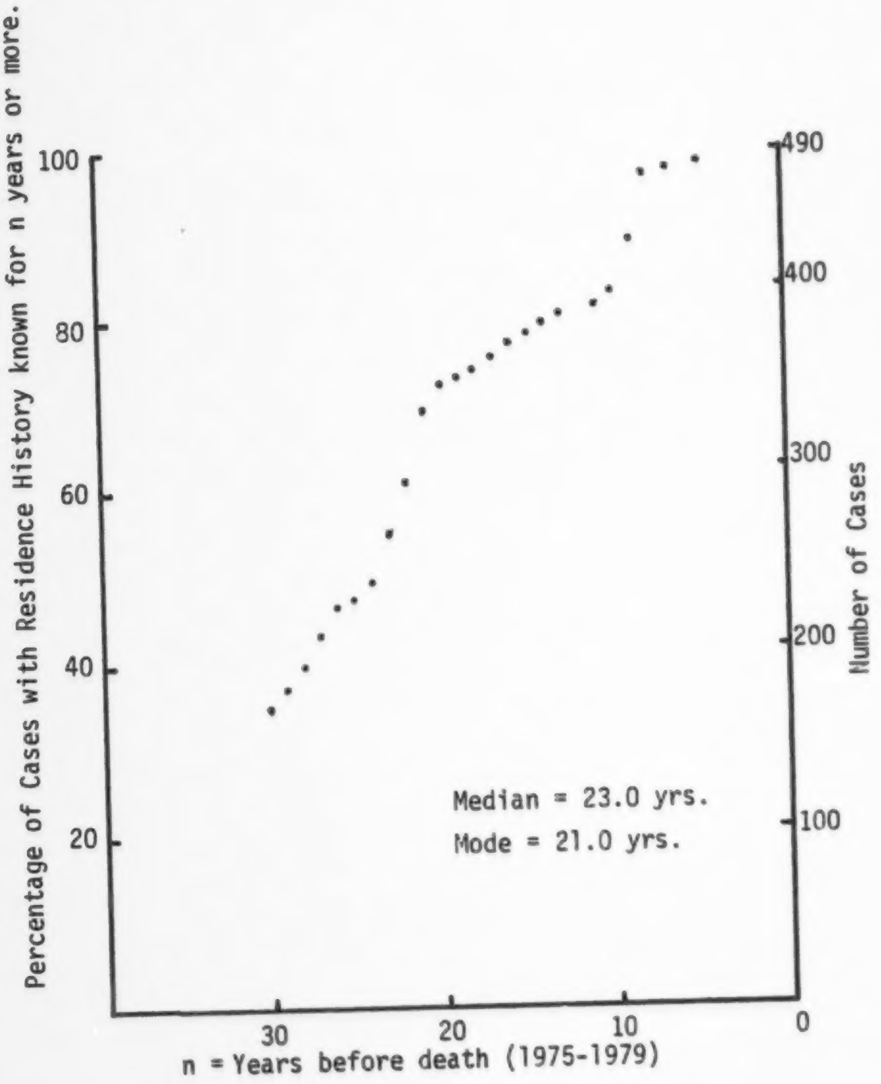
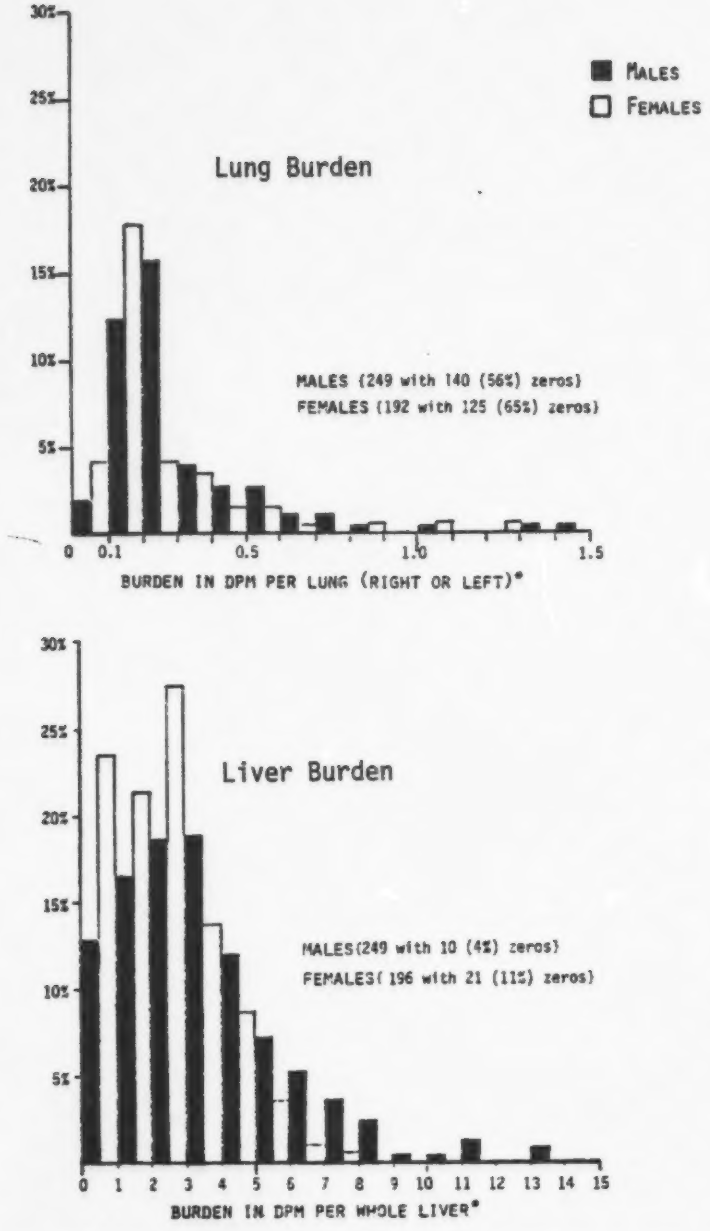


Figure 11. Residence History



*NOTE THAT THE LIVER BURDENS ARE AN ORDER OF MAGNITUDE LARGER THAN THE LUNG BURDENS

Figure 12. Distribution Histogram for Pu 239 Plus 240 Organ Burdens

Two conclusions are immediately evident from these plots. First, there is a great deal of scatter in the data, with some skewing, particularly among males.

In any analyses of the data, this between-person variability can be expected to completely overshadow the relatively small contribution made by the uncertainty of the counts. A calculation shows that the contribution of the counting errors to the variability of liver burden values (in terms of standard deviation) will typically be an order of magnitude smaller than the variability between people.

The second relationship which is apparent from the graphs is that the lung burdens are an order of magnitude smaller than liver burdens. This is the reason that the fraction of lung burdens that were reported as "No Pu Detected" is an order of magnitude greater than the same fraction for liver burdens.

A comparison of lung burden vs. liver burden in the same individuals shows them to be weakly ($r = 0.15$); but significantly ($P < 0.05$) correlated. This holds true for males alone but not for females, for whom the two burden measures are apparently uncorrelated. The relationship is somewhat stronger for those who smoke more than the median number of packyears ($r = 0.27$, $P < 0.01$), but is not significant among those who smoked below the median amount. As has already been mentioned, smoking and sex are confounded in this data set.

Figure 13 shows the distribution of observed liver and lung Pu 240/Pu 239 ratios, separately by sex. The distributions are similar for males and females although the distribution of ratios in livers from females is somewhat less symmetric than the other distributions. This figure shows a striking contrast between liver and lung ratios; and this is evident in both sexes. In both

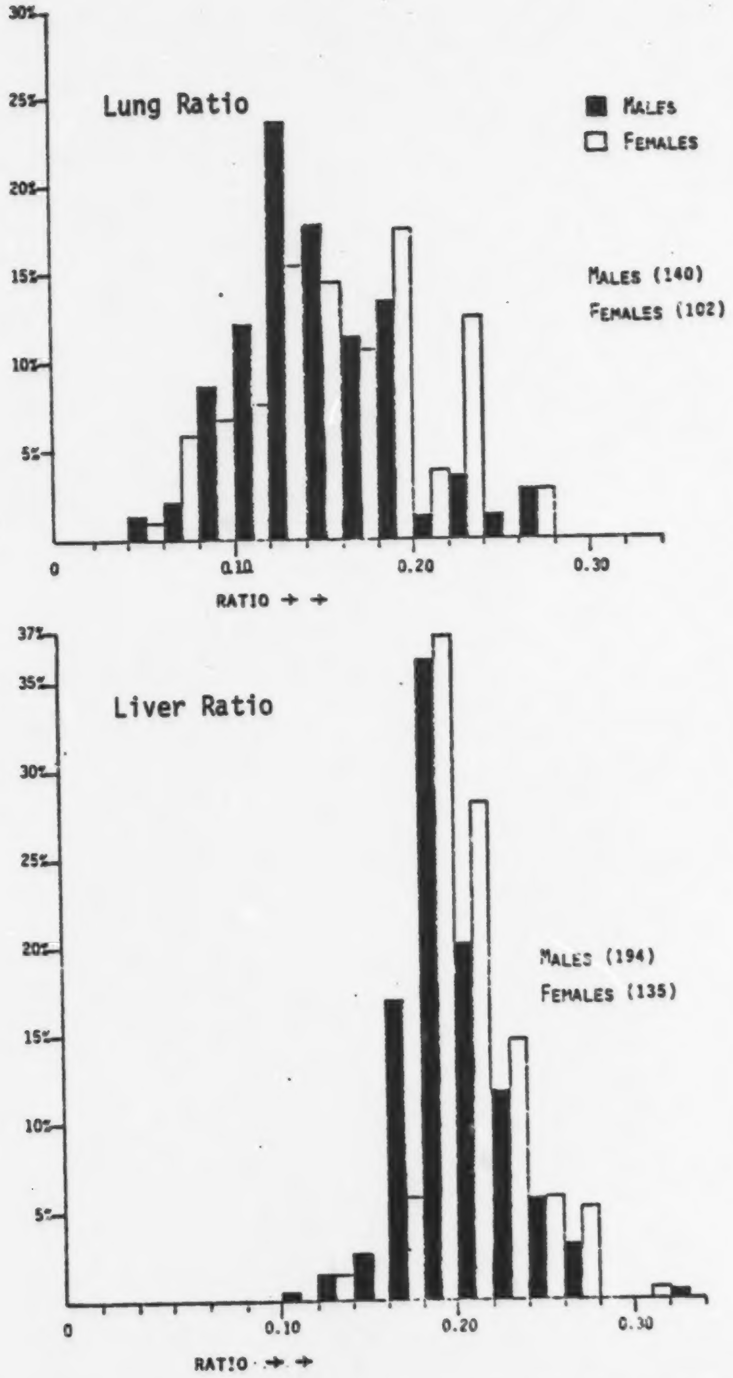


Figure 13. Distribution Histogram for Pu 240/239 Atom Ratios

cases, ratios in lung tissue span a range from 0.05 to 0.28, whereas there are few observed ratios below 0.16 in liver tissue from either sex. The correlation coefficient between lung and liver ratios in the same individual is both small and statistically nonsignificant.

Tables 17 and 18 show summary statistics on persons for various residence locations and times, and Table 19 stratifies the data by sex, age and smoking status. In these tables (17-19), burden values, which were reported as "No Plutonium Detected" are omitted.

In Tables 17 and 18 there are only two differences between means in adjacent rows (Areas A vs. B, B vs. C, etc.) which are of more than borderline statistical significance (at the 5 percent level). These are both in Table 17.b for the period of residence 1968-1970. The Pu 240/239 ratio in the lungs is slightly lower in Area A than in Area B, ($P < 0.05$), and the Pu burden in the lung as measured by MS is slightly higher in Area C than in Area B, ($P < 0.05$).

The data in Table 19 shows that sex, age and smoking history, in various combinations, are related to liver burden. Differences between mean liver burdens for male heavy vs. light smokers, between males and females of each age group, and between older and younger males were all significant. Females did not show an age difference in liver burden and smoking did not seem to have an influence in women. The only significant difference in plutonium isotope ratios in the liver was between older and younger females, the older women having a slightly lower ratio of Pu 240/Pu 239. In the lung, none of the burden means are significantly different from one another, and the only difference in Pu 240/239 ratio which is formally significant is between male heavy and light smokers, the heavy smokers having the lower Pu 240/239 ratio.

TABLE 17 (A)

STATISTICS ON THE POPULATION OF 473 INDIVIDUALS WHO HAD VALID PU MEASUREMENTS BY AREA OF RESIDENCE DURING MOST OF LAST 5 YEARS OF LIFE

		LIVER			LUNG		
		Pu Burden (dpm/organ)		Pu Ratio	Pu Burden (dpm/organ)		Pu Ratio
	†	APHA	MS	240/239	APHA	MS	240/239
AREA A	N	146	122	123	28	48	87
	$\bar{x}$	3.046	3.226	0.200	0.357	0.263	0.149
	SD	1.831	2.097	0.031	0.220	0.181	0.044
AREA B	N	139	115	115	36	56	86
	$\bar{x}$	3.150	3.431	0.195	0.323	0.217	0.162
	SD	1.837	2.103	0.026	0.302	0.146	0.046
AREA C	N	116	94	94	27	42	69
	$\bar{x}$	3.583	3.671	0.202	0.378	0.339	0.157
	SD	2.568	2.200	0.027	0.319	0.307	0.043
AREA D (Outside Colo.)	N	11	9	9	3	5	7
	$\bar{x}$	3.857	3.329	0.191	0.420	0.478	0.170
	SD	3.538	1.734	0.038	0.120	0.114	0.059
ALL AREAS	N	412	340	341	94	151	249
	$\bar{x}$	3.254	3.420	0.199	0.352	0.274	0.156
	SD	2.127	2.118	0.029	0.278	0.216	0.046

TABLE 17 (B)

STATISTICS ON THE POPULATION OF 473 INDIVIDUALS WHO HAD VALID PU MEASUREMENTS BY AREA OF RESIDENCE FOR 1968-70

		LIVER Pu Burden (dpm/organ)		LIVER Pu Ratio	LUNG Pu Burden (dpm/organ)		LUNG Pu Ratio
	†	APHA	MS	240/239	APHA	MS	240/239
AREA A	N	128	109	110	27	44	77
	$\bar{x}$	3.109	3.216	0.200	0.332	0.252	0.143
	SD	1.853	2.101	0.034	0.196	0.176	0.047
AREA B	N	136	112	112	32	49	83
	$\bar{x}$	3.108	3.395	0.193	0.320	0.213	0.162
	SD	1.801	2.103	0.025	0.315	0.138	0.047
AREA C	N	111	91	91	27	42	67
	$\bar{x}$	3.624	3.702	0.203	0.394	0.349	0.160
	SD	2.590	2.192	0.026	0.320	0.309	0.042
AREA D (Outside Colo.)	N	37	28	28	8	14	22
	$\bar{x}$	3.180	3.401	0.204	0.414	0.334	0.156
	SD	2.501	2.009	0.019	0.220	0.262	0.052
ALL AREAS	N	412	340	341	94	149	249
	$\bar{x}$	3.254	3.420	0.199	0.353	0.274	0.155
	SD	2.127	2.118	0.029	0.276	0.218	0.046

TABLE 18 (A)

STATISTICS ON THE POPULATION OF 473 INDIVIDUALS WHO HAD VALID PU MEASUREMENTS BY AREA OF RESIDENCE IN 1957 (FIRE ZONE SECTORS 3,4,5,6 and 7)

		LIVER			LUNG		
		Pu Burden (dpm/organ)		Pu Ratio	Pu Burden (dpm/organ)		Pu Ratio
	†	APHA	MS	240/239	APHA	MS	240/239
AREA A	N	71	59	59	18	20	20
	$\bar{x}$	2.904	2.925	0.198	0.273	0.227	0.147
	SD	1.898	2.032	0.034	0.178	0.149	0.046
AREA B	N	79	61	61	19	26	26
	$\bar{x}$	3.222	3.647	0.191	0.209	0.231	0.155
	SD	1.931	2.079	0.019	0.075	0.148	0.048
AREA C	N	82	69	69	17	31	31
	$\bar{x}$	3.862	3.676	0.205	0.338	0.290	0.158
	SD	2.712	2.153	0.025	0.331	0.280	0.044
AREA D (Outside Colo.)	N	34	26	26	4	11	11
	$\bar{x}$	2.904	3.274	0.209	0.398	0.366	0.183
	SD	1.876	2.173	0.022	0.304	0.334	0.048
ALL AREAS	N	266	215	215	58	88	88
	$\bar{x}$	3.294	3.413	0.200	0.280	0.268	0.157
	SD	2.213	2.112	0.027	0.225	0.230	0.047

TABLE 18 (B)

STATISTICS ON THE POPULATION OF 473 INDIVIDUALS WHO HAD VALID PU MEASUREMENTS BY AREA OF RESIDENCE IN 1957 (NON-FIRE ZONE SECTORS 1,2,8,9,10,11 and 12)

		LIVER Pu Burden (dpm/organ)		LIVER Pu Ratio	LUNG Pu Burden (dpm/organ)		LUNG Pu Ratio
	†	APHA	MS	240/239	APHA	MS	240/239
AREA A	N	4	3	3	3	2	2
	$\bar{x}$	3.233	3.273	0.183	0.253	0.165	0.130
	SD	2.259	2.521	0.000	0.170	0.000	0.000
AREA B	N	1	1	1	0	0	0
	$\bar{x}$	0.730	0.790	0.190	-	-	-
	SD	-	-	-	-	-	-
AREA C	N	3	3	3	1	1	1
	$\bar{x}$	3.287	3.580	0.203	0.560	0.690	0.130
	SD	1.054	1.080	0.000	-	-	-
AREA D (Outside Colo.)	N	21	16	16	5	6	6
	$\bar{x}$	3.712	3.711	0.197	0.534	0.435	0.140
	SD	2.773	1.751	0.026	0.344	0.442	0.050
ALL AREAS	N	29	23	23	9	9	9
	$\bar{x}$	3.499	3.510	0.196	0.443	0.403	0.137
	SD	2.538	1.775	0.021	0.294	0.383	0.039

TABLE 19

STATISTICS ON THE POPULATION OF 473 INDIVIDUALS

(Valid Pu Measurements by Smoking History,Sex, and Age)

		LIVER			LUNG		
		Pu Burden(dpm/organ)		Pu Ratio 240/239	Pu Burden (dpm/organ)		Pu Ratio 240/239
	†	APHA	MS		APHA	MS	
Male-heavy smokers ≥ 25 packyrs	N	152	133	134	43	58	58
	$\bar{x}$	4.107	4.206	0.196	0.318	0.266	0.146
	SD	2.408	2.322	0.030	0.180	0.141	0.040
Male-light smokers < 25 packyrs	N	87	71	71	20	28	28
	$\bar{x}$	3.173	3.243	0.196	0.447	0.377	0.169
	SD	2.315	2.120	0.025	0.350	0.315	0.043
Female-heavy smokers ≥ 25 packyrs	N	60	52	52	13	21	21
	$\bar{x}$	2.752	2.852	0.207	0.268	0.181	0.156
	SD	1.419	1.669	0.028	0.151	0.121	0.054
Female-light smokers < 25 packyrs	N	115	88	88	17	37	37
	$\bar{x}$	2.432	2.648	0.201	0.316	0.262	0.167
	SD	1.329	1.545	0.026	0.338	0.294	0.049
Males 65 yrs plus at death	N	142	124	124	38	49	49
	$\bar{x}$	4.165	4.356	0.195	0.384	0.319	0.154
	SD	2.414	2.185	0.028	0.281	0.210	0.042
Males under 65 yrs at death	N	97	80	81	25	37	37
	$\bar{x}$	3.184	3.120	0.197	0.320	0.279	0.151
	SD	2.301	2.273	0.030	0.198	0.229	0.042
Females 65 yrs plus at death	N	115	91	91	23	37	37
	$\bar{x}$	2.616	2.786	0.198	0.317	0.282	0.161
	SD	1.235	1.456	0.025	0.304	0.290	0.052
Females under 65 yrs at death	N	60	49	49	7	21	21
	$\bar{x}$	2.400	2.607	0.213	0.224	0.145	0.168
	SD	1.585	1.822	0.030	0.079	0.100	0.050

† N= the number of individuals in that category; $\bar{x}$= the mean value of measurements; SD= standard deviation.

REGRESSION ANALYSES

It is evident from the foregoing data presentations that sex, age, and smoking history are all related in some way to plutonium burdens. In fact, such relationships were anticipated prior to collecting these data. It is therefore appropriate to account for these variables in some way in analyses which attempt to investigate whether or not trends are present in the data with respect to peoples' residence locations in relation to Rocky Flats. Multiple regression techniques are the obvious methods of first choice with data of this sort.

Extensive two-way data plotting was undertaken initially in order to screen for heteroscedasticity, outliers, or pronounced non-linearity in the data generally, little evidence of any of these potential problems was found. The potential regressor variables themselves were usually only weakly correlated with one another, if at all, so that co-linearity among the independent variables did not seem to be a problem. In view of the extreme between-person scatter in most of the data, only the simplest linear models seemed appropriate to try, relying on the central limit theorem with large samples to make testing appropriate in view of the apparently minimal non-normality of the data.

Stepwise (step-up) procedures were used so as not to prejudge the importance of potential regressions and/or confounding variables. The stepwise regression program enters independent variables one at a time in the order in which they are most informative in accounting for the level of the dependent variable. After each entry of an independent variable, the significance of each of the coefficients of the variables then in the equation is calculated, together with other derived statistics. Multiple r^2- values and their changes with the addition of variables were monitored as indicators of the magnitude of potential effects of any statistically significant regressors. (The value of r^2 is usually taken to represent the amount of variability in the dependent variable which is "explained" by the independent variables.)

Most of the regressions were done only on persons who resided within 50 km of Rocky Flats, though some were attempted assigning a distance of 50 km to anyone living beyond that. All regressions were carried out separating the data by sex, as well as with the sexes pooled.

All of the regressions were carried out treating burden values which were reported by MCL as "No Pu Detected" as missing data. Some of these were repeated with zeros substituted for these missing values to see whether it would effect the search for trend. Obviously, mean values will be lowered by the procedure, but if the null hypothesis of no trend is true, it should not have an effect on regression coefficients.

LUNG AND LIVER PLUTONIUM CONCENTRATIONS

With plutonium concentrations in lung and liver tissue as the dependent variable, we carried out stepwise, multiple linear regression analyses using as independent variables: age, packyears of cigarette smoking and distance from Rocky Flats. These were done separately by sex and separately for selected sectors.

Average concentrations were low and associations with proximity to Rocky Flats not clearly shown. For those persons with residences within 50 km of Rocky Flats, average concentrations were: lung, 0.56 ± 0.97 and liver, 2.01 ± 1.29 dpm per kg of tissue, respectively (means ± standard deviations). Control values from persons with residences greater than 50 km were 0.52 ± 0.60 and 2.22 ± 1.74 dpm/kg.

Results of multiple regressions analyses with lung concentration as the dependent variable and age, packyears of smoking and distance from Rocky Flats as potential independent variables suggest a weak negative relationship of plutonium concentration in the lungs with distance, the concentration decreasing with increasing distance up to 50 km from Rocky Flats. This was seen only in males; the females showing no discernable pattern, even though the average concentrations were slightly higher in females than in males (0.65 dpm/kg vs. 0.49 dpm/kg).

For lung concentration in females, none of the potential regressor variables proved to significent, whereas for males, distance from Rocky Flats was significant overall ($P < 0.01$), but somewhat less significant ($P \gtrsim 0.10$) when the sample was restricted to males with residences within sector 5, of Figure 7; the relationship was not strong, with an r^2 value of 0.10. Packyears of smoking did not appear as a significant regressor variable for lung concentration of plutonium. Age, however, was positively related to lung concentration in males, with a coefficient of 0.0071 ± 0.0025 dpm/kg/yr.

In similar regression analyses with liver concentrations, there was no suggestion of a relationship with proximity to Rocky Flats. In all of the regressions with this dependent variable, age invariably showed up as the most important independent variable for both sexes and for both the total sample, as well as for those whose residences were within sector 5 of Figure 7. In addition, in males only, packyears of cigarette smoking was positively related to liver concentrations, both overall, and for sector 5 residences. These regressions explained about 17% of the variability in males and about 8 to 10% in females.

Among males, the liver concentration regression coefficient for age was 0.0328 ± 0.0079 dpm/kg/yr, and the coefficient for smoking was 0.0087 ± 0.0031 dpm/kg/packyear. In the liver concentration regression for females, the coefficient for age was 0.0217 ± 0.0053 dpm/kg/yr (means ± standard errors).

Similar regressions were performed after stratifying the sample by tumor status and sex. No consistent or strong patterns of response were discernable for either lung or liver concentrations. Three pathology strata were examined: no tumor reported; tumor or cancer as a major diagnosis; and, tumor or cancer found, but not a major diagnosis.

For the lung concentration data, age was marginally significant as a regressor in males with tumor as a major diagnosis. All other results were negative. In the liver concentration data, age appeared as a significant regressor for both the no tumor and tumor as a major diagnosis categories, and for both sexes within those categories. Smoking status in terms of packyears was significant for males in the no tumor group and in the minor tumor group, but not in the major tumor group.

LUNG AND LIVER PLUTONIUM ISOTOPE RATIOS

The ratio of isotope 240 Pu atoms to isotope 239 Pu atoms tends to be low (0.06 ± 0.01) in weapons grade plutonium relative to the average ratio in eastern Colorado for fallout plutonium (0.169 ± 0.004 mean ± standard deviation according to Krey, (1972)). Using a simple linear regression analysis with isotope ratio in lung tissue as the dependent variable and distance from Rocky Flats for residents within 50 km from Rocky Flats in sector 5 as the independent variable, a preliminary analysis showed a significant positive slope ($b=0.00124$, $P < 0.05$), which was essentially identical to the slope estimated from the data of Krey, (1972) on the same ratio in soil samples in the same area southeast of the Rocky Flats plant (Fig.14).

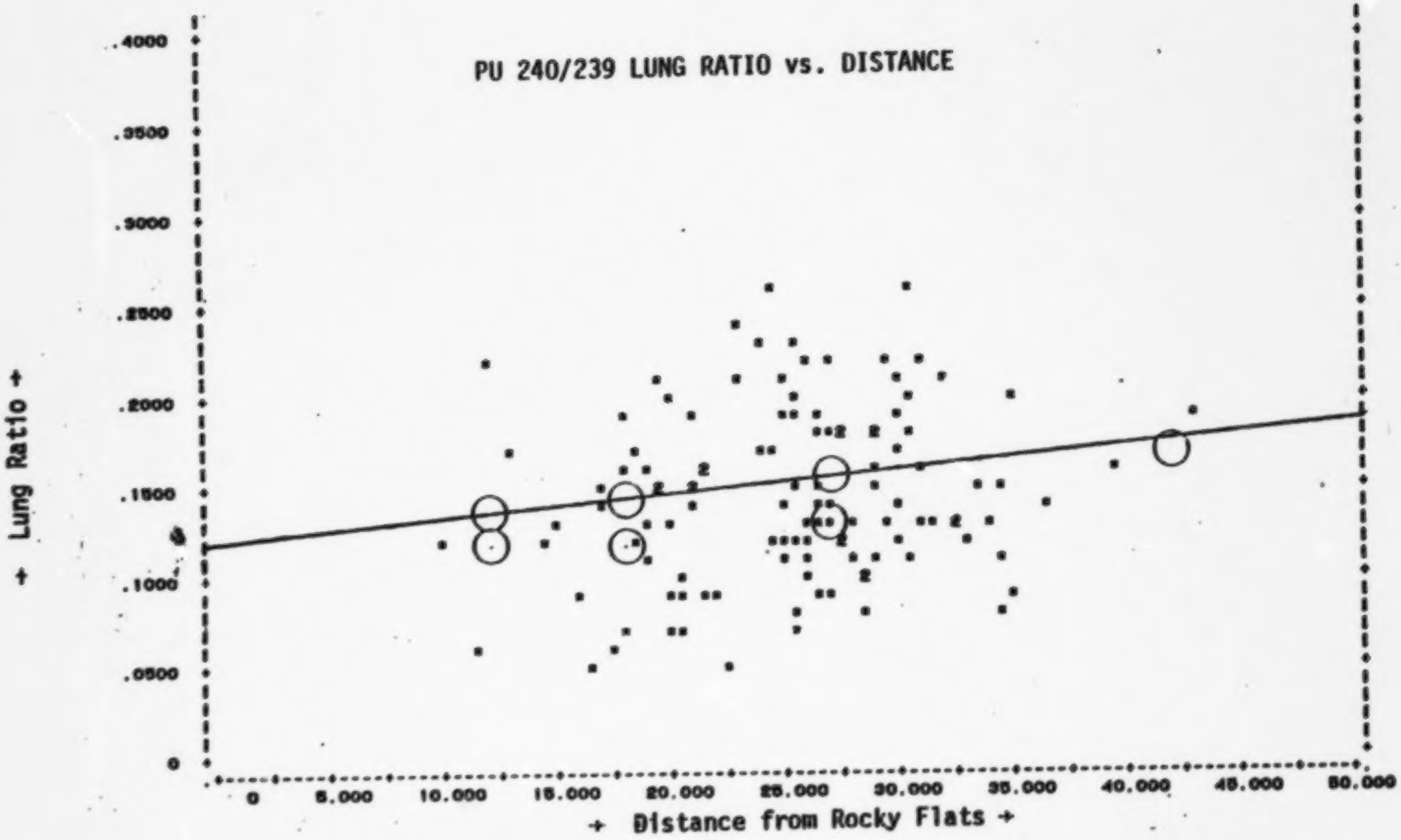


Figure 14. Scattergram of Pu 240/239 Isotope Atom Ratio in Lungs vs. Distance from Rocky Flats in km for Residents in Sector 5 within 50 km of Rocky Flats, During Most of Last 5 Years of Life.

(*)Asterisks represent individuals. Numbers indicate more than one individual.

The regression line for the data on residents is shown by a solid line.

(O)Large circles represent measurements of Pu 240/Pu 239 isotope ratios measured in soil by Krey.

The relationship was not a strong one, the correlation coefficient being $r = 0.16$, with substantial scatter about the line ($S_{y.x} = 0.05$). And, in fact, when the regression was repeated with age as a second independent variable in a stepwise program, age was selected at the first step ($P = 0.032$), and the coefficient for distance from Rocky Flats just missed significance at the 5% level when entered on the second step ($P = 0.054$), though the coefficient itself had not changed substantially from the simple regression estimate ($b = 0.00115$).

A total of 117 observations were included in these regressions (59 male, 58 female). When the multiple stepwise regression was repeated separately for each sex, the results were similar for males, though the distance coefficient was less significant ($P = 0.10$). In the regression on data from females, the independent variables entered in the opposite order, and neither coefficient reached significance at the 10% level. The females had a slightly higher average lung Pu 240/239 ratio than males (0.16 vs. 0.15), though not significantly so ($P > 0.2$, two-tail t-test).

In similar regressions (with lung isotope ratio as the dependent variable) for residents of all sectors around the plant taken together, distance did not appear as a significant regressor. Age and packyears of smoking were marginally significant in the total sample, but neither was significant for either sex separately.

In a preliminary look at the pathology data, stepwise regressions were run with Pu 240/239 ratio in lung tissue as the dependent variable, and age and packyears as the independent variables. These were run separately by sex (and both sexes combined), and separately by the three tumor classifications: (-) no cancer or tumor found at autopsy; (A) tumor or cancer a major diagnosis or underlying cause; and, (B,C, or D) tumor or cancer a past occurrence or minor autopsy finding. No discernible patterns were found in any of these regressions.

With Pu 240/239 isotope ratio in liver specimens as the dependent variable, multiple regressions were run similar to those which were run for the same ratio in lung tissue. For the liver specimens, the results were generally nonsignificant in regressions with age, packyears and distance from Rocky Flats as potential independent variables. The distance variable did not appear in any of the regressions, regardless of how the sample was stratified.

Age occasionally showed up as a significant variable with a negative relationship to liver ratio, and was usually more strongly associated in males than in females. This was true for those in sector 5 within 50 km of Rocky Flats, for the subsample with no tumor reported, and for those with a liver pathology code of 2, which includes conditions which would cause the liver to be congested and larger than normal at the time of death.

No other striking or consistent isotope ratio patterns were seen in regressions, stratified by sex, and run separately within each of the tumor pathology categories and within subsets of the liver pathology categories.

A multiple regression with liver ratio as the dependent variable, entering stepwise as independent variables; age, sex, packyears and direction from Rocky Flats during 1957, showed a weak, but statistically significant relationship between liver ratio and direction from Rocky Flats during the 1957 period. The people who resided within 50 km of Rocky Flats in sectors 3 through 7, that is east and south from Rocky Flats during the 1957 fire, had a lower average ratio of Pu 240/239 in their livers than did those living in the other sectors and in the areas more than 50 km from Rocky Flats.

Looking at the multiple regressions for males and females separately, this relationship holds significantly for males alone; but for females alone it is not statistically significant. For both sexes together, and for males alone, it is a weak relationship, explaining only about 5% of the variation in liver ratio, but it is statistically quite significant (P = 0.002 for males and females together, and P = 0.005 for males alone).

LUNG BURDEN

Lung burden was left blank in our data set unless the record showed that we had at least 90% of either the right or left lung. We have valid measurements of plutonium lung burden for only 176 individuals (0.284 ± 0.017 dpm, mean ± standard error of the mean (SEM)). The great majority of lung assays were reported as "No Pu Detected".

Because of the large proportion of missing values, extensive analysis seemed unwarranted. A scattergram of the valid lung burden data by residence, within sector 5 (A+B), shows a great deal of variation as well as a questionable outlier (Figure 15).

Comparing the distribution of distances from the RFP between those who had valid lung determinations and those whose lung Pu determinations were reported as "No Pu Detected," we found no obvious trend. There was a deficit of cases reported "No Pu Detected" among those residing within 15 km of the RFP, but there was a deficit also among those residing between 25 and 50 km, and among those residing more than 50 km away; the remaining distance having about an equal proportion of values reported as "No Pu Detected".

There seemed to be a weak tendency for lung determinations reported as "No Pu Detected" to occur among younger persons, but only in women.

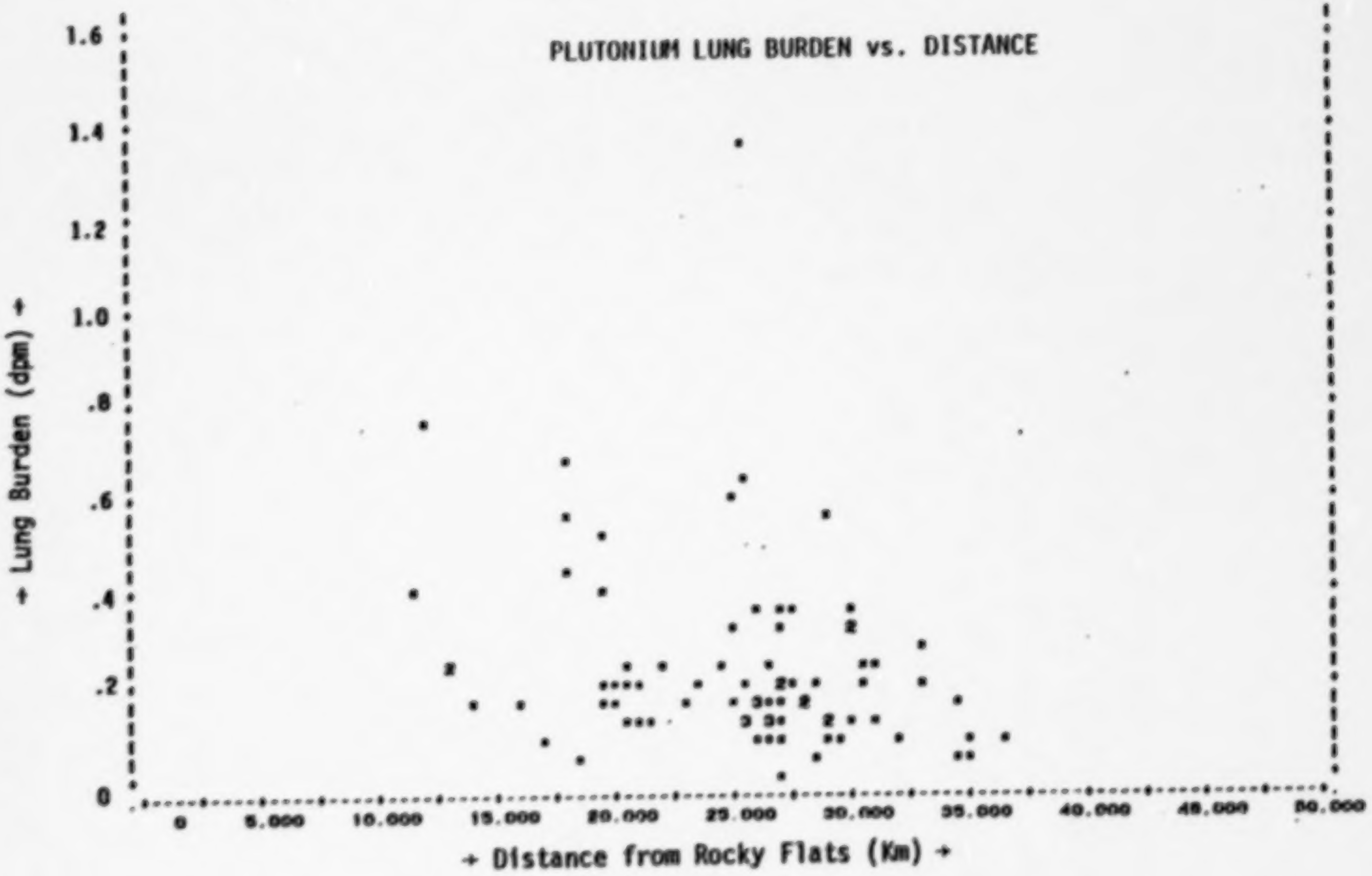


Figure 15. Scattergram of Lung Burden vs. Distance from Rocky Flats for Residents of Sector 5, within 50 Km of Rocky Flats, During Most of Last Five Years of Life.

(*) Asterisks represent individuals. Numbers indicate more than one individual.

The relationship of "No Pu Detected" in lungs with smoking, on the other hand, was quite consistent and striking. A regression of the percentage of values reported as "No Pu Detected" on packyears of smoking is significant ($P < 0.02$), and yields an intercept of $a = 0.67$ and a slope of $b = 0.002$. (See Figure 16) Evidently, nonsmokers and light smokers were more likely to have "No Pu Detected" in their lungs than were heavy smokers.

LIVER BURDEN

Multiple regression analyses with liver burden as the dependent variable were run with the following independent variables; smoking history measured in packyears, age, sex, and distance of residence from Rocky Flats. The distance was calculated for the residence during each of three time periods: the last five years of life, the period 1968-1970, and the time of the fire at Rocky Flats in 1957. In addition, we looked at the data separately for the two sexes and for people who had resided in the southeast direction from Rocky Flats as compared with those who had resided in other directions.

In those regressions in which sex was treated as a dichotomous independent variable, it was almost always included as a significant regressor, usually following the inclusion of age and packyears of smoking. Therefore, it appeared that regressions run separately for males and females would be more informative in allowing us to draw conclusions about the other regressor variables.

Males had a slightly but significantly higher average liver burden than females: 3.28 ± 0.17 vs. 2.54 ± 0.12 dpm/organ (mean ± SEM). They also smoked significantly more by quite a large amount: 36.92 ± 2.72 vs. 15.24 ± 2.21 packyears. Average age was about the same: 65.4 ± 1.2 for males vs. 68.6 ± 1.5 for females, as was the average distance for residences within 50 km of Rocky Flats, for the three time periods (about 24 km).

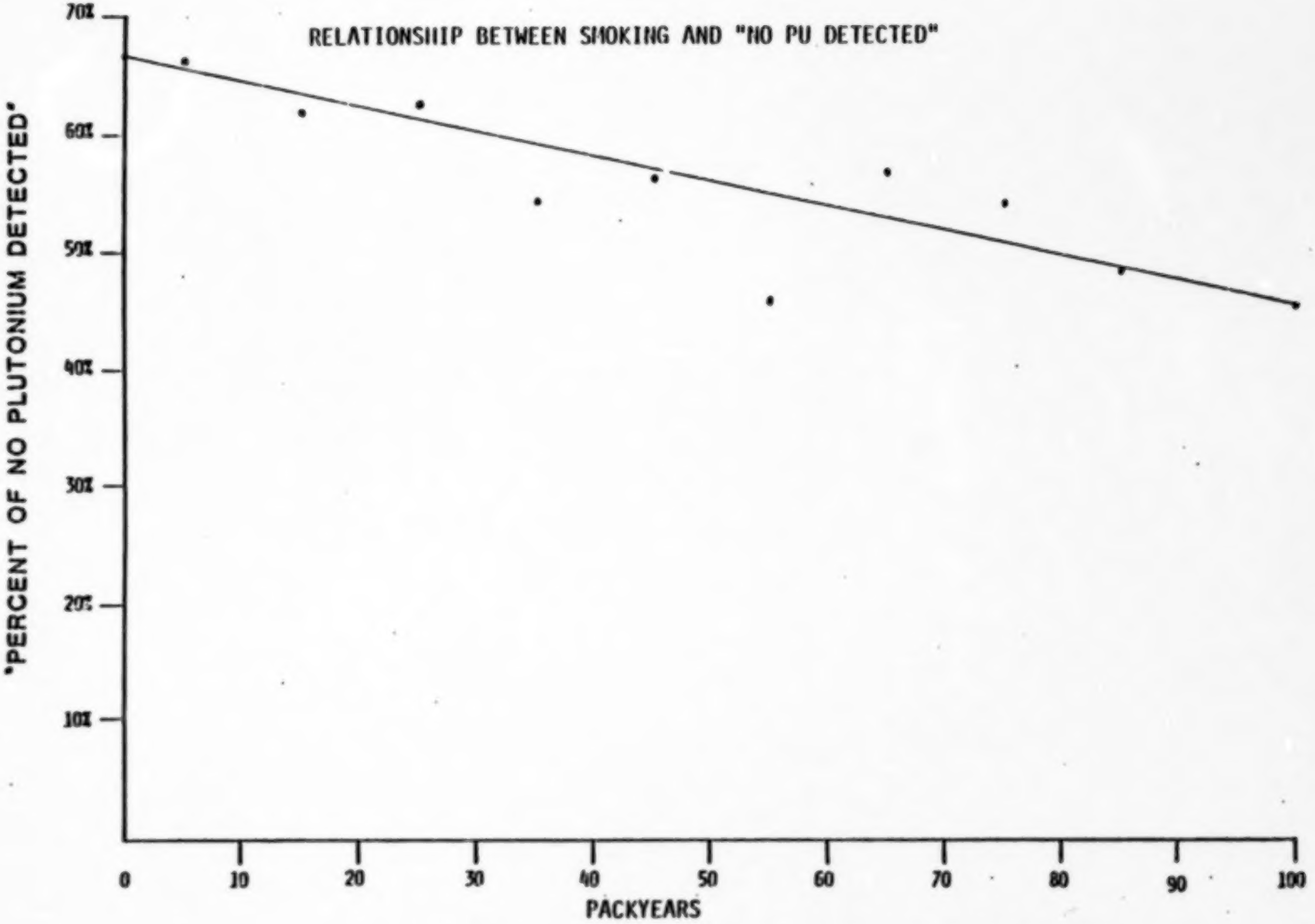


Figure 16. Percent of Individuals Who Had "No Pu Detected" In Their Lungs, by Amount of Smoking History (Males and Females Combined)

In a number of regressions for the various time periods and for various subsets of the females (all females, those in sector 5, various pathology breakdowns, etc.) age was the most likely variable to be selected as a first regressor in a stepwise program; but when it was selected, it was usually not highly significent ($0.05 < P < 0.10$). In brief, liver burden appears to be both low and weakly related to any of the regressor variables in females.

In males, on the other hand, both age and packyears of smoking were usually positively and significantly related to liver burden. Distance of residence from Rocky Flats did not show any consistent relationship. Overall, for males, the regression coefficient for age was 0.046 ± 0.015 dpm/year (coefficient ± standard error), and that for packyears of smoking was 0.014 ± 0.005. The intercept for this regression was 0.26, but was nonsignificant.

All of the foregoing regressions using liver burden as dependent variable were repeated substituting zeros for the blank values that were reported as "No Pu Detected". The results were essentially identical. Mean values of some of the variables were changed, but not by important amounts.

SECTION 5

DISCUSSION

COMPARISON WITH OTHER STUDIES

There have been two studies of plutonium in tissues of comparable numbers of nonoccupationally exposed people in the USA which reported values for tissue concentration of plutonium (McInroy, 1979 and Fisenne, 1979). These studies also reported estimated values for total organ burdens which were calculated by multiplying the concentration found in the tissue sample by the standard weight of the whole organ for a standard reference man; they did not use the actual weight of the organ at the time of death, as we did. They did not measure the Pu 240/Pu 239 isotope ratios; nor did they get sufficiently detailed information about smoking or places of residence to permit comparison with our findsings. The age distribution of the subjects in McInroy's study is roughly comparable to ours, but the Fisenne study utilized only accidental deaths of essentially healthy individuals, so they had cases with relatively few pathological conditions and a much larger proportion of young people. Both McInroy and Fisenne estimated the median values for their populations by plotting the individual measurements on probability paper and interpolating or extrapolating to the 50th percentile. We have not used this method because we have no reason to suppose that the distribution of tissue concentrations in our data would be a normal or log-normal distribution. If there were a significant local source of plutonium, the distribution might even be bimodal.

We have not addressed the issue of the parametric form of the distribution of values in our sample, since it is irrelevant to the basic questions posed and only has analytical importance for assurances that the assumptions necessary to justify multiple regression analyses are not badly violated.

Autopsy data are certain to be unrepresentative of the general population for most purposes, but we have neither a prior reason to suppose, nor results which suggest, that our data are unrepresentative with respect to lung and liver plutonium deposition, at least on an age and sex specific basis.

It is of interest to note that our mean value for lung concentration on people who had lived in eastern Colorado (0.52 dpm/kg ± 0.06 mean ± SEM) is very similar to the median value estimated for the Colorado population by McInroy (0.43 dpm/kg) and is only slightly higher than the median value (0.13 dpm/kg) estimated by Fisenne for that much younger and healthier population in New York City. For liver concentration, our mean for eastern Colorado (2.22 dpm/kg ± 0.09 mean ± SEM) is only slightly higher than both the estimated median of McInroy for Colorado (1.66 dpm/kg) and that of Fisenne for New York (1.39 dpm/kg). These differences could easily be accounted for by differences in ages, sex ratios, or smoking habits of the population samples.

SIGNIFICANCE OF PU 240/PU 239 ATOM RATIOS

The mean Pu 240/239 atom ratio in plutonium from global fallout (F) and from various releases of plutonium at the Rocky Flats Plant (RFP) are markedly different. According to Krey, et al, the Pu 240/239 atom ratio for global fallout is 0.176 with a standard deviation of 0.014 and ranges from 0.12 to 0.21 around the world (Krey, 1976a), and the Pu 240/239 atom ratio for plutonium released by RFP is 0.06 ± 0.01 (Krey, 1972). Since plutonium released by RFP has an isotope ratio different from the average for global fallout, the following equation has been used to estimate the relative contribution of plutonium in a sample from the RFP releases as compared to the contribution from global fallout (Krey, 1976b).

$$\frac{(\text{Pu activity})_{RFP}}{(\text{Pu activity})_{F}} = \frac{(C_F - C_s)\ (1 + 3.60\ C_{RFP})}{(C_s - C_{RFP})\ (1 + 3.60\ C_F)}, \quad \text{...........Eq.(1)}$$

where:

C_F = Pu 240/239 atom ratio in global fallout

C_{RFP} = Pu 240/239 atom ratio from RFP

C_s = Pu 240/239 atom ratio in sample

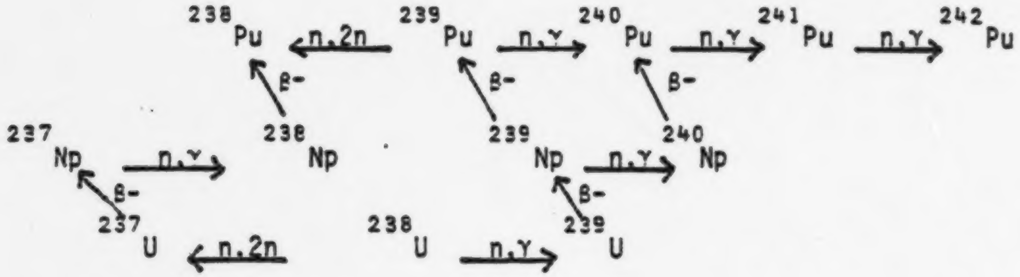
Krey used the techniques defined by Eq. 1 on soil samples to estimate the quantity of plutonium that had been released offsite by the RFP (Krey, 1976b). Hardy, et al, applied the technique to sediment samples from Standley Lake near Rocky Flats to estimate the time deposition pattern for the RFP releases (Hardy, 1972).

For the approach defined by Eq. 1 to be a valid method for estimating the fraction of the plutonium that came from the RFP releases the following assumptions must apply: 1) the Pu 240/239 atom ratios of C_{RFP} and C_F are well characterized, and 2) only plutonium from global fallout and RFP releases are present. An examination of these assumptions is presented below.

1. How well characterized are the Pu 240/239 atom ratios in RFP releases and global fallout?

Weapons Grade Plutonium

RFP processes weapons grade plutonium. This material is produced by neutron capture reactions with U-238 and subsequently by beta decay to form plutonium isotopes 238, 239, 240, 241, and 242.



Neutron irradiation conditions may vary slightly from batch to batch; however irradiation conditions have been maintained constant enough so that the majority of weapons grade plutonium has a Pu 240/239 atom ratio that falls within the range defined by Pu 240/239 = 0.06 ± 0.01. It has been experimentally verified that the effluent released from RFP has a Pu 240/239 atom of 0.06 ± 0.01 (Krey, 1972). Therefore, one may conclude that the Pu 240/239 atom ratio of RFP weapons grade plutonium is essentially constant.

Global Fallout Plutonium

The variations in the Pu 240/239 atom ratio in global fallout plutonium are more complex. Global fallout plutonium is best described as a composite that was mainly produced by the mixing of debris clouds formed by the atmospheric detonations of nuclear devices. Each nuclear detonation contributes fallout plutonium that contains a complex mixture of plutonium isotopes produced by various mechanisms. A portion of the plutonium may originate as unburned weapons grade material (ratio 0.06 ± 0.01) expelled from the device.

Additional quantities of plutonium are produced by the nuclear transmutations that occur subsequent to the detonation. The quantity of plutonium produced and the atom ratio of the plutonium produced varies with the design and yield of the device (Krey, 1976a). High yield nuclear detonations have produced Pu 240/239 isotope ratios as high as 0.33 ± 0.02 (Mocent, 1976).

The different debris clouds may not completely mix in the atomosphere (AEC, 1973; Efurd, 1977). In addition, any one individual may not have been equally exposed to every fallout cloud that passed over the area of residence. Therefore, it is theoretically possible for an individual to have in his tissues Pu 240/239 ratios ranging from 0.06 to 0.33 as a result of fallout alone. In fact, among the 51 valid measurements of the Pu 240/Pu 239 ratio in the lungs of individuals who had always resided more than 50 km from the RFP, but within Colorado east of the Continental Divide, and who had neither been occupationally exposed nor resided in Pu contaminated areas such as the Western Slope, the ratios actually ranged from 0.05 to 0.26, with a mean of 0.16. For a geographically defined population that has not been occupationally exposed to weapons grade plutonium, one would expect the mean Pu 240/239 atom ratio measured in tissue samples to be similar to the mean ratio measured in soil samples in the area, and one would expect a fair amount of scatter around these mean ratios.

2. Are there other sources of plutonium in Colorado besides global fallout and RFP weapons grade plutonium?

As of September 30, 1980 there had been 565 announced tests at the Nevada Test Site (NTS). Ninety-seven of the 114 above-ground tests produced measurable amounts of radiation off the Test Range Complex boundaries. Forty-three of the 451 announced subsurface shots produced measurable amounts of radiation off the Test Range Complex boundaries (Hicks, 1981). Plutonium originating at the NTS has lowered the Pu 240/239 atom ratio of soil samples collected at Salt Lake City to 0.08 (Hardy, 1972). As would be expected, the ratio in soil of eastern Colorado, except for soil near the RFP is considerably higher than the ratio in Salt Lake City and is slightly lower than the ratio in Tulsa, Oklahoma, where it is 0.1719 ± 0.014 which is essentially the same as the global average of 0.176 ± 0.014 (Krey, 1976a). Eleven measurements of the Pu 240/239 ratio in soil in eastern Colorado in locations where contamination from Rocky Flats plutonium was considered unlikely (i.e. more than 5 km west or more than 35 km east of Rocky Flats), gave an average ratio of 0.169 ± 0.004 mean ± standard deviation with a range from 0.164 to 0.179 (Krey, 1976b; Merrill, 1977). This suggests that a very small fraction of the plutonium in the soil of eastern Colorado may have been carried by the wind from the Nevada Test Site.

A fourth source of plutonium may be found in Colorado; that coming more recently from nuclear weapons tests in the Peoples' Republic of China. There were approximately 20 tests, done in the atmosphere since the signing of the Limited Test Ban Treaty in 1968, which would have contributed minimal amounts of plutonium to the global plutonium inventory of approximately 325 KCi that had been injected into the atmosphere from tests prior to 1968 (Hardy, 1973). However, the fact that these Chinese tests were relatively recent means that, at least for lung tissue where the retention half-time is only about 500 days (Martin, 1976), one cannot rule out the possible effect of these Chinese tests on the Pu 240/239 ratios found in lungs of people who had recently been living in Colorado.

Atmospheric transport and diffusion processes would have dispersed the NTS and Chinese debris clouds before they reached Colorado, so that plutonium originating from these sources would probably be randomly distributed in the soil and in the population of eastern Colorado. By contrast, weapons grade plutonium released from the RFP would probably be locally concentrated near the RFP. Thus, an increasing gradient in the Pu 240/239 ratio with increasing distance from the RFP would be consistent with what one would expect from the effects of plutonium contamination emanating from the plant. The lack of such a gradient would be consistent with the absence of RFP contamination. The data on Pu 240/239 ratio in lung tissue gathered in this study contain a suggestion that such a gradient may exist for people who lived in the southeast sector, but certain caveats must be borne in mind in the interpretation of these data. First, there are many missing values of this ratio because of the generally low burdens in lung tissue. However, a comparison of the distribution of distances for those lung samples with and without a valid determination revealed no systematic pattern in missing values with distance. Second, the statistical relationship is very weak, particularly after age is taken into account, and although consistent in both sexes, falls short of conventional levels of significance for each sex taken separately ($P > 0.10$). Third, it is axiomatic that the demonstration of a formally statistically significant relationship does not necessarily imply a causal relationship. Nevertheless, the similarity with the same gradient in Pu 240/239 ratios, independently observed in soil samples in the same direction, is striking. In summary, we feel that with all of these considerations in mind, we cannot rule out the possible conclusion that people who had lived southeast of the RFP and lived near to the plant for the last 5 years of life, may have a larger proportion of weapons grade Pu in their lungs than did people who had lived father away, with a pattern similar to that of plutonium found in the soil in the same area.

Our finding that this relationship between Pu 240/239 and distance was not statistically significant when residents of all sectors around the plant were considered together is not surprising in view of the asymmetrical distribution of plutonium in the soil around the RFP. The RFP plutonium was found to have been distributed almost entirely in the easterly and southerly directions from the RFP (Krey, 1976b).

We found that the Pu 240/239 ratios in the liver were significantly higher than in the lung (See Figure 13) and also that the total amount of plutonium burden in liver was an order of magnitude greater than in lung (See Figure 12). Both of these observations are explained by the fact that retention half-time of plutonium in the liver (14,600 days) is thirty times longer than in the lung (500 days), (Martin, 1976). Thus, we would expect the liver to reflect the accumulation of plutonium over a person's whole lifetime and to accumulate a much greater plutonium burden. The Pu 240/239 ratio would thus be less affected than the lung by recent exposures to weapons grade plutonium of low ratio and more affected by relatively heavy fallout exposures during the 1950's and 1960's.

The Pu 240/239 ratio of global atmospheric plutonium has varied from year to year, depending on the types of atomic bombs being tested. The greatest contribution to radioactive debris in the world's atmosphere was during the 1963-4 atom bomb testing program when the average Pu 240/239 atom ratio for atmospheric plutonium was 0.22. The bulk of this material had fallen out from the atmosphere onto the earth's surface by 1968. During 1968, after the signing of the Limited Test Ban Treaty, the average ratio was 0.18 (Efurd, 1977).

An atmospheric Pu 240/239 ratio of 0.159 ± 0.011 was reported for Ramsey Air Force Base, Puerto Rico, for the Fall of 1975 (Efurd, 1977), but we have insufficient information to assess the influence of the high yield atom bomb tests detonated in China in 1976 and 1980.

From the above, it appears that since 1963-4 the average ratio of global Pu 240/239 had in general been falling from around 0.22 in 1963 to around 0.16 in 1975. This would explain the difference between our findings of the mean liver ratio (= 0.199 ± 0.002 SEM) and the mean lung ratio (= 0.156 ± 0.003 SEM), but we have no rationale for our observation that older females in our study have a very slightly lower average liver Pu 240/239 ratio than do younger females (0.198 vs. 0.213), see Table 19.

PROBLEMS WITH THE "CONTROL" AREA

The majority of our control sample came from Colorado Springs and Pueblo, which are respectively 100 km and 170 km south of Denver. This area may have had different weather conditions which could have influenced the amount of plutonium fallout from weapons testing at the Nevada Test Site. Also, during the 1957 fire at Rocky Flats, the wind was blowing toward the south (Hammond,1971). Unfortunately, we have not been able to get measurements of the plutonium 240/239 ratios or of the concentration of plutonium in the soil around Colorado Springs and Pueblo, so this area is not, in fact, established as a suitable control area. The population living more than 25 km from Rocky Flats can, however, serve as a control population for those living closer; and the upwind population can be considered a control for the downwind population. Examination for gradients of plutonium burden and Pu 240/239 ratio with both distance and direction from Rocky Flats appears, therefore, to be a reasonable approach, utilizing primarily the population within 50 km of the plant.

Before starting this study, it was our hypothesis that measurements of the total organ burden of plutonium would be more meaningful than the organ concentration (as measured in dpm per kg of wet tissue at the time of death). This was based on our recognition of two problems related to tissue fluid changes: 1) Tissue concentration of plutonium would depend on the degree of swelling or hydration of the tissue at the time of death; whereas total liver burden would presumably remain relatively constant in spite of the changes in fluid content which are likely to occur near the time of death. For example, acute hepatitis or acute biliary obstruction in the liver could cause the liver to double in volume near the time of death due to fluid. Then assuming the total amount of plutonium in the liver remained constant, a calculation of the tissue concentration, using the liver weight at the time of autopsy, would give a value of approximately one half of what the concentration would have been under normal conditions. 2) The other problem is that slicing the tissues during the post mortem examination allows much of the tissue fluid and blood to drain off. Thus there is likely to be a rather large discrepancy between the weight of the whole organ when it is first removed from the body and the time it is finally placed in a plastic bag and frozen. This tissue fluid and blood, as we found in specimen #375-9, may contain a small fraction (about 1.5%) of the total plutonium burden of the organ, but by far the largest part of the plutonium burden seems to be rather firmly fixed to the tissue itself and does not drain off with the fluid. Thus, when tissue fluid has drained off during the autopsy, the resulting calculation of tissue concentration from the drained specimen gives a biased value which is higher than it would have been if the fluid had not drained off.

For the above reasons, we felt that total organ burden, as calculated in this study, would be a more meaningful measurement than tissue concentration. This supposition is lent support by our findings that in general, data relating to total liver burden showed more regular patterns and stronger relationships with regressor variables as compared with data relating to liver concentration.

OVERALL MEANING OF FINDINGS

It should be borne in mind that the reported results are to some extent selected from among a great many analyses performed, and this could have an effect on the true probabilities associated with putatively significant relationships, but this concern is mitigated by the fact that the questions addressed are those which the study was originally designed to investigate.

The findings of the multiple regression analyses show generally weak relationships, if any, between the dependent variables: plutonium burden, tissue concentration, or isotope ratio and the independent variable: distance of residence from Rocky Flats, for various periods of time. At least one of the variables: age, sex, or smoking history was almost invariably selected at the first or second step in the regression attempts. However, whenever one of the residence distance measures entered, it was never at the first step, always weakly related to the dependent variable, and sometimes showed a weaker relationship within sector 5 than overall, at least for measures of burden.

Although the data on the ratio of Pu 240/239 in the lung hold a suggestion of a gradient, the results on burdens are not consistent in this respect, which is not too surprising since place of residence would not be expected to be very definitive of overall lifestyle (e.g. smoking habits) or potential for exposure. In the multiple regressions for liver burden, age was selected as the first regressor variable in females, with distance from RFP entering at the second regression step with a negative, but nonsignificant slope coefficient. Among males, both age and packyears of smoking entered the regression with significant coefficients before distance from RFP was introduced with a nonsignificant positive slope, so that overall, there is no consistent evidence of a gradient of liver burden with distance from RFP. In several such regressions, the standard errors of the slope coefficients for distance from RFP were typically on the order of 0.01 to 0.02 dpm/km. Given a nonsignificant slope, the 95% confidence limits for the true slope would be about 0.02 to 0.04 dpm/km (0 ± 2 SEM). That is, given our observed between-person variability of liver burden and our sample sizes, one would have to observe a slope at least as large as 0.02 to 0.04 dpm/km in order to declare it statistically significant. Slopes of this magnitude would be indicative of a change in liver burden over a 50 km range of about 1 to 2 dpm. Since the mean liver burden in our sample is about 3 dpm, this means that studies of this sort should be able to detect a gradient indicative of a 50% change in mean burden over a 50 km range. This does not seem like a large difference in comparison with the wide variability which is related to other factors, the range of observed liver burdens being from 0 to 14 dpm (Figure 12).

In sum, the ratio data contain a weak suggestion of RFP plutonium contamination of people who had lived in sector 5, but the burden data indicate that, if such contamination occurred, it was in small enough amounts that its contribution to total burden is not distinguishable from that contributed by fallout, given the amount of variability in this surveillance system.

AGE AS A FACTOR IN PLUTONIUM BURDEN

When we ran multiple linear regressions with plutonium burden as the dependent variable, age was invariably selected as the regressor variable most closely related to liver burden in both sexes. The results differed, however, between males and females. For males, the estimated regression on age was:

$$B = 0.26847 + 0.04607A,$$

where B = liver Pu burden in dpm/organ

A = age in years.

For females, the regression was:

$$B = 1.53105 + 0.01470A$$

The average line for females has both a larger intercept and smaller slope than that for males (See Figure 17). (Since most of our sample was over 40 years of age, inferences about younger ages would be tenuous.)

Fox, et al. reported a linear fit to their liver Pu concentration data as:

$$C = 0.91356 + 0.01682A,$$

where C = liver Pu concentration in dpm/kg

A = age in years.

Figure 17 shows the average liver burden estimated in this study, related to age, for males and females separately (solid lines); and average liver burden for males and females together, related to age, as estimated from McInroy's data by Fox (broken lines). (Fox, 1980; McInroy, 1979)

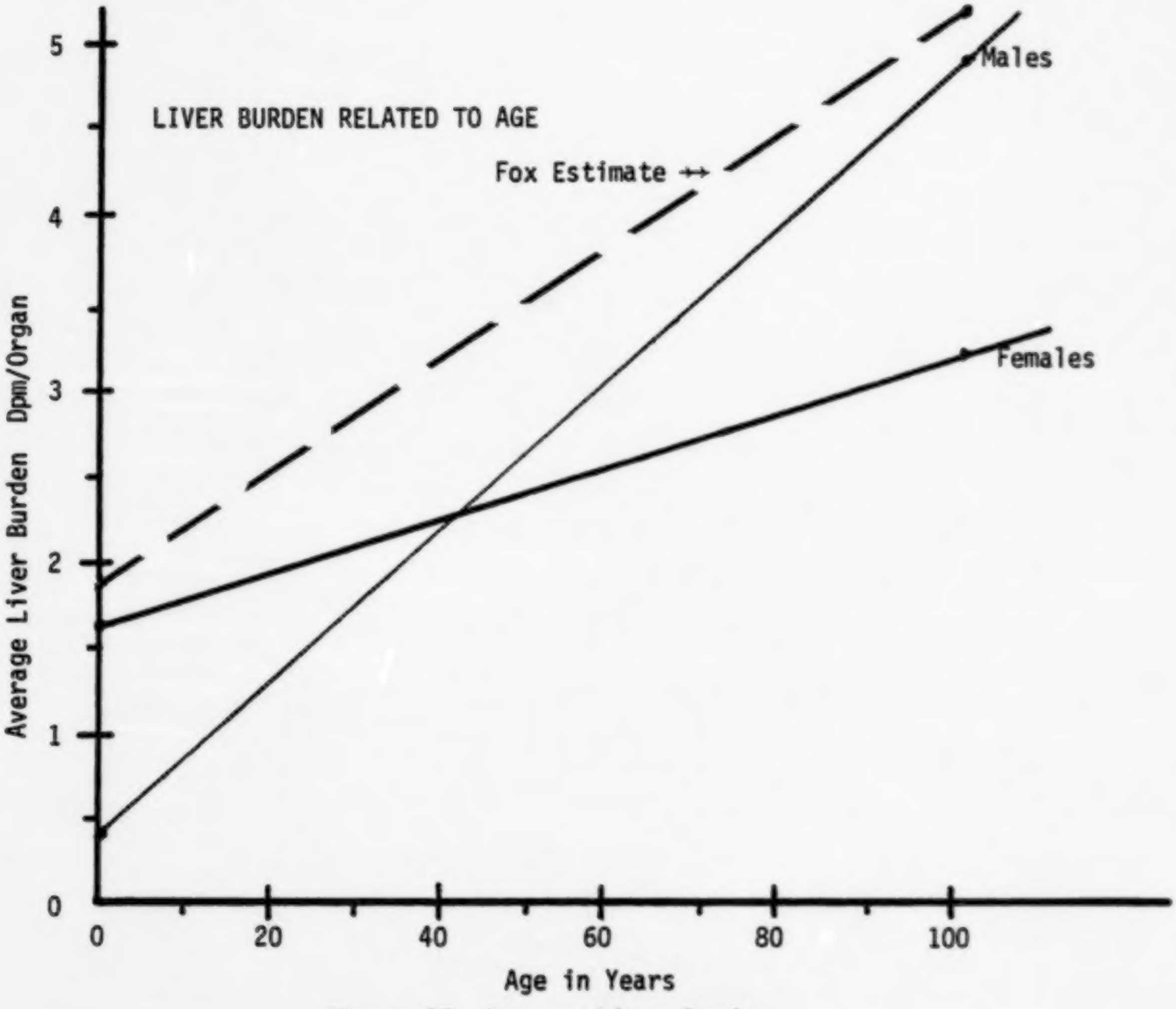


Figure 17. Average Liver Burden

Organ burden equals average weight times concentration ($B = kC$, when k is average organ weight in kg). Using this relationship, Fox's equation would become:

$$B = kC = 0.91356k + 0.01682kA,$$

and, for illustrative purposes, if we assume an average weight of $k = 2$ kg for a liver, this becomes:

$$B = 1.827 + 0.034A.$$

This gives a slightly higher average burden estimate at all ages than our results, but given the amount of variability inherent in this sort of data and the assumptions made, the two independent results certainly seem comparable.

There are several possible explanations for the finding that older people have larger plutonium burdens in their liver and lungs than do younger people; probably all of these operate together.

In the first place, the peak of plutonium air concentration from worldwide fallout occurred in 1963 and it dropped during the next four years by a factor of 15 (Efurd, 1977). Young people born since then would, therefore, have had considerably less exposure to worldwide fallout plutonium than older people. This would also be true for young people who had lived in the locally contaminated area near Rocky Flats where the concentration of plutonium in air peaked in 1957 (Hammond, 1971) and 1968-70 (Seed, 1971) but has been relatively low since 1970 (Volchok, 1976).

In the second place, young people probably have healthier lungs in general; therefore we might assume that they would be better able to get rid of inhaled particulates than would older people. That is, we might postulate that the cilia in the bronchial tubes and bronchioles would be in better shape and more active in young or middle age people, because of being less exposed to toxic substances than older people. Thus, the film of mucus containing inhaled particulates would be more actively moved up the bronchial tree to the pharynx, where the plutonium would be either coughed out or swallowed. (Because of its low solubility, probably only very little plutonium is absorbed from the gastro-intestinal tract (Bair, 1974)). The cough reflex in young or middle aged people is also apt to be more vigorous than in older, especially sick, people in the last years of life.

In the third place, during the 1950's and the 1960's, older people were still smoking more than younger people; it's only in recent years that teenagers have begun to smoke so much (Last 1980). Moreover, the influence of smoking is evidently cumulative; the more years a person has smoked, the more damage probably has been done to the lungs. This accounts for the correlation of incidence of cancer of the lung with packyears of smoking, e.g., (Last, 1980).

Fourthly, it is obvious that for people born since man's first use of plutonium in 1945, all other things being equal, an older person would generally have been exposed to plutonium in the air for a longer time period than would a younger person.

Finally, at least for growing children, the amount of air breathed in per unit time increases with increasing size which increases with age. This probably has little impact on our population because of the very small number of children, (See Figure 9).

All of the above factors would tend to give older people a larger plutonium burden. We can think of few reasons for the reverse effect. If children were playing in contaminated soil, they might get more in their lungs than their parents; but adults working in the garden, or on the job under dusty conditions in windy contaminated areas, might be similarly exposed.

TOBACCO AS A SOURCE OF PLUTONIUM?

The results of the multiple regression analyses suggest, among other things, that a male at the average age of this sample (65.4 years) would have 1.5 times as much plutonium in his liver if he had been an 80 packyear smoker as he would if he had been a nonsmoker. For a 50 packyear smoker at the average age, the ratio would be 1.3. If this relationship is real, it could result from either a higher intake of plutonium among smokers or impaired clearance from the body. The possibility that cigarette tobacco is contaminated with plutonium is worth investigating by doing some laboratory measurements of plutonium in tobacco, but it seems unlikely that this will turn out to be the explanation. Dr. Edward Martell(4) has studied the polonium 210 content of tobacco and cigarette smoke and finds that polonium in the tobacco does come through the cigarette in the main stream smoke because it is vaporized by the burning tobacco. By contrast, he says that lead 210 does not come through to any significant degree. It is not vaporized and therefore tends to get filtered out by the cigarette itself. He thinks that plutonium, if present in tobacco, would also be filtered out by the cigarette itself.

The other obvious hypothesis is that the toxic and irritating substances in cigarette smoke damage the clearing mechanisms of the lungs, thereby preventing the natural elimination of particles.

If the excess liver burden of plutonium in heavy smokers were coming from the cigarette tobacco itself, we would expect that it would have the same ratio of Pu 240/239 as does global fallout, and thus heavy smoking would

(4) Dr. Martell is currently at the National Center for Atmospheric Research, Boulder, Colorado.

tend to cause a higher ratio in our population. However, we find that in our multiple regression analyses with liver or lung ratio as the dependent variable, and entering age, distance, and packyears of smoking as the independent variables, there is no significant relationship between packyears of smoking and liver or lung ratio; what relationship there is tends to be negative. These data do not support the hypothesis that the plutonium burden of smokers is coming from the cigarettes themselves.

SECTION 6

SUMMARY AND CONCLUSIONS

This study of plutonium in human autopsy tissue from deceased Colorado residents showed a large variation in lung and liver burdens of plutonium. Much of the variation is related to age, sex and smoking history, and relatively little, if any, to the distance from the Rocky Flats Nuclear Weapons Plant of an individual's former residence. Heavy smokers had significantly more plutonium in their lungs than did light smokers or nonsmokers.

Regarding the question of the Rocky Flats Plant as a source of the plutonium, the results of this study are neither strongly positive nor strongly negative; one cannot conclude from these data that releases of plutonium from Rocky Flats have not contributed to human plutonium burdens, but the data do show that the total amount of plutonium in these human tissues is small and is not very different from that observed by other researchers who have studied people from other locations in the USA.

Mass spectrometer analysis of the isotopes of plutonium found in the lungs of former residents of the Denver area revealed atom ratios of Pu 240/Pu 239 which were consistent with independently observed atom ratios in the local soil. This leads to the possible conclusion that part of the plutonium in these lungs, having an atom ratio typical of weapons grade plutonium, may have come from the Rocky Flats Plant, like plutonium contamination of the local soil; but amounts are not distinguishable from those found in people in control areas.

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APPENDIX A

PARTICIPATING HOSPITALS

Boulder Community Hospital, Boulder, Colorado

Boulder Memorial Hospital, Boulder, Colorado

Children's Hospital, Denver, Colorado

Colorado General Hospital, Denver, Colorado

Colorado State Hospital, Pueblo, Colorado

Denver General Hospital, Denver, Colorado

Lutheran Medical Hospital, Wheat Ridge, Colorado

Park View Hospital, Pueblo, Colorado

Penrose Hospital, Colorado Springs, Colorado

Presbyterian Hospital, Denver, Colorado

Rose Memorial Hospital, Denver, Colorado

Saint Anthony Hospital, Denver, Colorado

Saint Luke's Hospital, Denver, Colorado

Saint Mary-Corwin Hospital, Pueblo, Colorado

Valley View, Thornton, Colorado

APPENDIX B

INFORMED CONSENT

University of Colorado Medical Center
Consent to Obtain Tissue at Autopsy
for the Plutonium Study

(Patient I.D. Stamp Here)

In order to determine whether plutonium concentrations are higher in people who lived near the Rocky Flats Nuclear Weapons Plant than in people with no known exposure to this man-made radioactive element, a study is being conducted by the University of Colorado Medical Center and the U.S. Environmental Protection Agency.

Tissue samples (liver, lung, bone, gonad, and adrenal gland) will be taken at autopsy, immediately after death, of persons whose next of kin agree to grant permission for tissue study. Subjects must have lived in the sampling areas during 1968 and for at least five years since that date. Information regarding the possible exposure of the deceased to plutonium will be obtained from the next of kin. People who have worked at Rocky Flats or any other facility which processes plutonium are not eligible for this study.*

Signed____________________________________Date________________
(next of Kin)

1st Witness (If permission by telephone)____________________________

2nd Witness (If permission by telephone)____________________________

Attending physicians of this patient, next of kin, or their legal counsel can obtain the data from our studies of plutonium in the tissues of this patient by mailing a request to:

EPA-UCMC Plutonium Study
Department of Preventive Medicine
University of Colorado Medical Center
4200 E. 9th Avenue C-245
Denver, Colorado 80220
Phone 394-7252 (day)
399-1211 (night)

The request must state the hospital number, date of death, and date of birth since patient names are stricken from the study records in order to maintain confidentiality.

* The Transuranium Registry is interested in obtaining tissues from former employees of Rocky Flats and will pay for tissue samples collected for the Registry.

PLEASE RETAIN THIS PAGE IN THE PATIENT'S MEDICAL RECORD

APPENDIX B, CONTINUED

University of Colorado Medical Center
Consent to Obtain Tissue at Autopsy
for the Plutonium Study

(Patient I.D. Stamp Here)

RESIDENCE HISTORY

	YES	NO	NOT SURE
Since 1968, was the deceased living most of the time in Colorado?	☐	☐	☐

OCCUPATIONAL HISTORY

To your knowledge has the deceased ever worked in the Rocky Flats Nuclear Weapons Plant or other atomic energy plant or any other place where he or she might have been exposed to plutonium?

	YES	NO	NOT SURE
Worked at Rocky Flats or other?	☐	☐	☐

(If answer is "Yes", these tissues are not suitable for this environmental (EPA) study, but the Transuranium Registry would be willing to pay for these tissue samples - contact Mr. Clayton Lagerquist at (303) 497-2452)

CONTACT INFORMATION (Please Print)

If we need to clarify details of the above questions, where may we contact you?

Your name____________________________

Address____________________________

____

Phone____________________

Relationship to Deceased______________

ATTENDING PHYSICIAN

Name____________________________

EPA Contract No. 68-03-2217
Form Approved OMB No. 158-R-0128

APPENDIX C

TISSUE COLLECTION PROTOCOL

1. The tissue is to be retained for this study if: (a) the deceased lived in Colorado on the consent form during the year 1968 and five years since 1968 (that is to say the residence history has been answered "Yes" or "Not Sure"), and (b) the deceased had not worked at a facility where plutonium is located (that is to say the occupational history was answered "No" or "Not Sure").

2. If the deceased had an occupational exposure to plutonium, the tissue would not be useful for the purpose of this study; however, the Transuranium Registry would be interested in and willing to pay for the collection of these tissues. In this case, phone Mr. Clayton Lagerquist at 497-2452.

3. A set of Mylar bags, wrapped in a four-gallon plastic bag, is provided for each set of tissues collected.

4. At autopsy time the autopsy number is filled out on each of the Mylar bags. In addition, this tissue collection form is filled out.

5. Please get tissue from normal areas as far as is possible and avoid retaining tissue from serious epidemic infectious diseases such as hepatitis, plague, etc.

6. Each tissue sample is placed in the appropriately labeled Mylar bag. In addition, the liver and lung tissue are weighed and placed in the 1000 ml. beakers to shape the frozen tissue in a convenient form for analysis.

7. All tissue is then placed in a freezer until frozen.

8. After freezing, the tissue along with this tissue information sheet and a copy of the autopsy permission form, is placed in the plastic four-gallon bag. This keeps the tissue and information for each set separate.

9. The results of the study will be reported as amount of plutonium per body organ. Therefore, we need to know what percentage of the whole organ has been included in our sample.

APPENDIX C, CONTINUED

A. DATA ON TISSUES COLLECTED (please fill out completely)

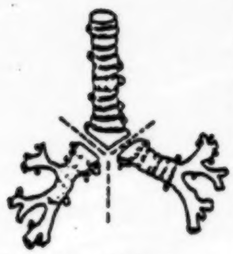
Name of Deceased ____

Hospital # ____________________ Pathologist ______________________________

Autopsy # ______________________________ Date __________________________

Was the body embalmed before autopsy? YES ____ NO ____

The following amounts of tissue are requested:



(submit either lung)

LUNG: One whole lung, ie., all three lobes of the right lung or both lobes of the left lung, including the tracheobronchial lymph nodes. If a few small pieces of tissue are removed for histological studies, the usefulness of the tissue for this study will not be affected. However, we cannot use a specimen with less than 90% of the lung remaining after autopsy. Please include the main bronchus with attached lymph nodes, cut at the carina of the trachea, and approximately half of the inferior tracheobronchial lymph nodes from the same side as the lung which is being submitted.

Lung submitted: Right _____ Left _____ (please check)

Total Original Weight of Right Lung ______________ grams

Total Original Weight of Left Lung ______________ grams

Weight of Tissue submitted ______________________ grams

LIVER: Please submit approximately 700 grams.

Original Total Weight of Liver __________________ grams

Weight of Tissue Submitted ______________________ grams

GONAD: Please submit as much gonadal tissue as possible.

Approximate percentage of total gonadal tissue submitted _________ %

ADRENAL: Please submit both adrenals, or as near 100% as possible.

Approximate percentage of total adrenal tissue submitted _________ %

RIB: Please submit approximately 125 grams.

B. ADDITIONAL DATA NEEDED (please fill out as completely as possible)

Date of birth of deceased (or age): _____________

Home Address of deceased: ____

Clinical diagnoses: ____

Tentative Pathological diagnoses: ____

____

If embalmed before autopsy, Name of Mortuary: ____________________________

APPENDIX D

LOGBOOK ENTRY

327

Name: John Doe

Sex: M

Address: 1234 Main Street
Any Town, Colorado

Age: 74

Organ Weights:

2327 - Liver (right half)	619.7 grams	6327 - Adrenal	36.6 gms
3327 - Lung (right)	383.6 grams	7327 - Liver (left half)	482.0 gms
4327 - Rib	606.6 grams	8327 - Lung (left)	420.5 gms
5327 - Gonad	Absent		

Autopsy No.: A-126-78 Hospital: St. Luke's Date: 9/02/78

2327 - 624.6 gms check weight (double bagged) Sent to NERC/LV 7/31/79

3327 - 389.1 gms check weight (double bagged) Sent to NERC/LV 7/31/79

2327 and 3327 returned from NERC/LV on 8/07/79

MCL
Lab # 495 - 7327 - 495 gms check weight to MCL 8/08/79
Lab # 496 - 8327 - 435 gms check weight to MCL 8/08/79
Lab # 493 - 2327 - 494.3 gms check weight to MCL 8/08/79
Lab # 494 - 3327 - 350.0 gms check weight to MCL 8/08/79

APPENDIX E

TELEPHONE INTERVIEW PROTOCOL

Hello, my name is (interviewer) from the University of Colorado, School of Medicine, Plutonium Study.

May I please speak to (next of kin)

Hello, is this (next of kin)? This is (interviewer) of the University of Colorado Medical School.

Dr. Cobb and I wrote you a letter last week explaining about the plutonium study, and saying that I would be calling.

I am calling to get a little more information about (decedent) in connection with our joint study with the EPA regarding plutonium in the environment. You probably remember signing a permit for this study as part of the autopsy study, performed on (date of autopsy). Can you spare about five minutes now to answer three or four more questions?

RESIDENCE HISTORY

I see that (decedent) used to live at (address at death). Can you tell me how long (decedent) lived there?

IF NO Other Informants who might be able to tell me? (name, address and phone number).

IF YES Did (decedent) live there all of the time, except for short trips and vacations, since January 1, 1956?

IF NO What other places did (decedent) live during those years since January 1, 1956? (Address) (City) (State).

Did (decedent) live on the Western Slope of Colorado, Utah or Nevada during the 50's or early 60's?

OCCUPATIONAL HISTORY

We are interested to know whether or not (decedent) ever worked in a place where (he/she) might have been exposed to radioactive materials like plutonium. About how far back would you say you are familiar with the kind of work (decedent) was doing?

IF NOT BACK TO 1944,

Who would be likely to know about this? (name,address; phone number) (and relationship to deceased). Get names of several informants, if indicated.

As far as you know, did (decedent) ever work in a place like the Rocky Flats Plutonium Plant or any other AEC facility like Los Alamos, N.M.; Oak Ridge, Tenn.; Hanford, Washington; Arco, Idaho; Lawrence Livermore or Lawrence Berkeley Labs in California; The Manhattan Project, etc.

(Name of employer, dates and kind of work)

Was (decedent) involved with any atom bomb explosion or testing operation, either in this country or overseas, like the first test in New Mexico in 1945, Hiroshima, Nagasaki; the South Pacific tests at Enewetok or Bikini; or tests at the Nevada Test Site in this country?
(place, dates, and kind of involvement)

SMOKING HISTORY

The final thing we would like to know is whether or not (decedent) used to smoke tobacco at any time during his/her life.

IF YES Did (he/she) smoke cigarettes, cigars or a pipe?

How many packs (or cigars, or pipes) per day, at the most?

How long did (he/she) continue smoking? (years)

Did (he/she) ever stop smoking? When?
For how long?

Did (he/she) inhale the smoke?

Thank you very much for your assistance.

Do you have any questions to ask me about this study?

Follow-up on Autopsy Permit Form OMB Approval #158-R-0128, University of Colorado - EPA Contract No: 68-13-2217

APPENDIX F

TELEPHONE INTERVIEW RECORD

DATE OF INTERVIEW__________________ NAME______________________
(Day, Month, Year) (Deceased)

NAME OF INFORMANT_______________________ RESIDENCE__________________

RELATION TO DECEASED__________PHONE#________ __________________

RESIDENCE

(Circle) Same as above address since 1956 YES NO

or

Different since 1956 DATES ADDRESS MUNICIPALITY COMMENTS
(More room needed continue on Page 2 under comments)

1.
2.
3.

(Circle) Were any of the above addresses in Nevada, Utah or Colorado Western Slope
YES NO

Other Informants 1. ________________ 2. ________________
________________ ________________

OCCUPATION

(Circle) No Plutonium Processing Exposure

or

Possible Exposure DATES ADDRESS MUNICIPALITY COMMENTS

1.
2.
3.

(Circle) No Testing Site Exposure

or

Possible Testing Site Exposure DATES ADDRESS MUNICIPALITY COMMENTS

1.
2.
3.

(Circle) Other Informants 1. ________________ 2. ________________
________________ ________________

APPENDIX F, CONTINUED

SMOKING HISTORY

(Circle) Never Smoked

or

Smoked

TYPE	AMOUNT	PERIOD
Cigarettes	Packs per	How many yrs
Cigars	Per	how many yrs
Pipes	Per	How many yrs

(Circle) Stopped Smoking What year ______

For what period of time From 19___ to 19___

(Circle) Inhaled Deeply

INTERVIEW TIME

Minutes spent completing form ______

Minutes spent on other with next of kin ____

Name of Interviewer______________________

COMMENTS:

Want copy of summary YES NO Circle one

APPENDIX G

LETTER TO NEXT OF KIN

UNIVERSITY OF COLORADO
MEDICAL CENTER
4200 EAST NINTH AVENUE
DENVER, COLORADO 80262

SCHOOL OF MEDICINE
DEPARTMENT OF PREVENTIVE MEDICINE
AND COMPREHENSIVE HEALTH CARE

(Letter to next of kin)

Dear   :

As you may remember, the University of Colorado, Department of Preventive Medicine and the United States Environmental Protection Agency (EPA) are doing a study to find out whether plutonium and other radioactive substances from Rocky Flats are getting into the bodies of people living in this area. We very much appreciate the permission you gave for us to retain tissue samples of __________in connection with this study.

If you don't mind, one of our staff, Roxanne Taggart will be telephoning you in the next week or two. For the purpose of this study, we need to confirm the past residence and occupation of _______. We also need to know about the smoking history of the people in this study, because cigarette smoking may influence the way plutonium gets absorbed in the lungs. These questions will only take two or three minutes.

If you have moved or will not be available at the telephone number we have for you, _____; or if you would rather not be called at this number for any reason, please telephone us at 394-7252, or send us a post card.

Thank you again for your help in this study.

Yours sincerely,

John C. Cobb, MD, MPH

OMB-158-R-0128

THE UNIVERSITY OF COLORADO IS AN EQUAL OPPORTUNITY EMPLOYER

APPENDIX H

STEP-BY-STEP PROCEDURE: ANALYSIS FOR PLUTONIUM ISOTOPES

Step-By-Step Procedure For Analysis

4.1 Preparation of Tissue for Analysis.

4.1.1 Remove the frozen tissue from the packaging and place it in a tared 1500 ml pyrex beaker.

4.1.2 Weigh the beaker on a triple beam balance. Record the wet weight of the tissue, to the nearest 0.1 grams.

4.1.3 Oven dry the tissue at 110° for 48 hours.

4.1.4 Char the tissue on an asbestos covered hot plate for 48 hours.

4.1.5 Ash the tissue by heating at 550°C for 48 hours in a high temperature furnance.

4.1.6 Cool the furnace to 150°C and remove the sample. Let the beaker cool to ambient temperature.

4.1.7 Weigh the beaker on the triple beam balance. Record the ash weight of the tissue, to the nearest 0.1 gram.

4.1.8 Add several boiling chips, 500 ml 6M hydrochloric acid, 10 ml 48% hydrobromic acid and 5 ml 48% hydroiodic acid to the beaker.

4.1.9 Boil the solution on a covered hot plate until the volume is reduced to 250 ml.

4.1.10 Add minimal amounts of concentrated nitric acid to the boiling solution to evolve any excess bromine and iodine.

APPENDIX H, CONTINUED

4.1.11 Repeat step 4.1.10 until cessation of bromine and iodine fumes.

4.1.12 Continue heating until the volume is reduced to 100 ml.

4.1.13 Cool to room temperature. Filter the solution through S and S No.588 prefolded 12.5 cm filter paper into a 1000 ml volumetric flask.

4.1.14 Place the filter paper in a No. 0 porcelan crucible and ignite in a muffle furnace at 900°C for four hours.

4.1.15 Cool the crucible to room temperature. Dissolve the residue in 6$\underline{M}$ hydrochloric. Filter the solution through S and S No. 588 filter paper into the 1000 ml volumetric flask.

4.1.16 Bring the flask up to volume with 6$\underline{M}$ hydrochloric acid.

4.2 Equilibration of Sample and Tracer.

4.2.1 Transfer a 500 ml aliquot of the solution 4.1.16 to a clean 1500 ml beaker.

4.2.2 Add boiling beads, 1 ml of Pu 242 tracer and 2 ml of lanthanum chloride carrier.

4.2.3 Boil the solution on a hotplate until the volume is reduced to 100 ml Cool the solution to room temperature.

4.2.4 Add 8 drops of saturated ammonium iodide.

4.2.5 Add 1 ml of concentrated nitric acid and heat the solution to evolve the excess iodine.

4.2.6 Repeat 4.2.5 until all excess iodine is evolved.

4.2.7 Continue heating the solution until the volume is reduced to 5 ml.

4.2.8 Cool to ambient temperature.

4.3 Separation and Purification of Plutonium

4.3.1 Quantitatively transfer solution 4.2.8, using 6M hydrochloric acid, to a 40 ml centrifuge cone.

4.3.2 Add 15 ml of diethyl ether and shake the mixture for 2 minutes. Extract and discard the ether layer.

4.3.3 Repeat 4.3.2 until the ether layer is colorless.

4.3.4 Place the centrifuge cone in a hot water bath to volatize any excess ether.

4.3.5 Add 15 ml concentrated ammonium hydroxide. Centrifuge and discard the supernatant. (Plutonium and several other elements form hydroxides that coprecipitate with the $La(OH)_3$ carrier.)

4.3.6 Add 10 ml 6M sodium hydroxide. Digest in a hot water bath for 15 minutes. Centrifuge and discard the supernatant.

4.3.7 Dissolve the hydroxide precipitate in 5 ml HNO_3. Heat to a boil using a Bunsen burner.

4.3.8 Cool to room temperature and add 10 ml distilled water.

4.3.9 Reprecipitate the hydroxide with concentrated ammonium hydroxide. Centrifuge and discard the supernatant.

4.3.10 Wash the precipitate in 10 ml distilled water. Centrifuge and discard the supernatant.

4.3.11 Dissolve the precipitate with 10 ml concentrated hydrochloric acid that contains 1 drop concentrated nitric acid.

APPENDIX H, CONTINUED

4.3.12 Load the solution on a pre-equilibrated anion exchange column. The 1x5 cm column contains Dowex 1x8, 50-100 meash resin. The column is pre-equilibrated with two 10 ml portions of concentrated hydrochloric acid that contains 1 drop of concentrated nitric acid.

4.3.13 Wash the column with 20 ml concentrated hydrochloric acid.

4.3.14 Wash the column with 20 ml concentrated hydrochloric acid that contains 2 drops 48% hydrofluoric acid.

4.3.15 Elute the plutonium from the column into a 40 ml Nalgene cone by adding 10 ml concentrated hydrochloric acid that contains 5 drops saturated ammonium iodide.

4.3.16 Add 10 drops lanthanum nitrate carrier, 2 drops zirconium nitrate carrier,(10mg/ml $ZrCl_3$) 5 ml $5\underline{M}$ hydroxylamine hydrochloride and 8 drops of ammonium iodide to solution 4.3.15.

4.3.17 Heat in a hot water bath for 10 minutes.

4.3.18 Add 2 ml 48% hydrofluoric acid and heat for an additional 10 minutes. Centrifuge and discard the supernatant.

4.3.19 Dissolve the precipitate by adding 5 ml saturated boric acid and 4 ml concentrated nitric acid.

4.3.20 Transfer the solution to a 40 ml centrifuge tube with distilled water.

4.3.21 Reprecipitate the plutonium and lanthanum carrier by adding concentrated ammonium hydroxide.

4.3.22 Repeat steps 4.3.19 through 4.3.21

4.3.23 Dissolve the precipitate in 5 ml concentrated nitric acid. Heat the solution to boiling over a Bunsen burner.

4.3.24 Cool the solution to room temperature. Add 10 ml distilled water. Reprecipitate the plutonium and lanthanum carrier with concentrated ammonium hydroxide. Centrifuge and discard the supernatant.

4.3.25 Wash the precipitate with distilled water. Centrifuge and discard the water.

4.3.26 Repeat steps 4.3.11 through 4.3.15. Elute the plutonium fraction into a 125 ml Erlenmeyer flask.

4.3.27 Add 12 drops of concentrated sulfuric acid and heat on a covered hot plate until the evolution of dense SO_3 fumes.

4.3.28 Cool the solution.

4.4 Electrodeposition.

4.4.1 Transfer solution 4.3.28 with water to the plating cell.

4.4.2 Add 1 drop of methyl red indicator.

4.4.3 Add minimal amounts of concentrated ammonium hydroxide to make the solution basic. Reacidify to the end-point, pH6, with 1.5$\underline{M}$ sulfuric acid.

4.4.4 Lower the anode into the plating cell until it is about 1 cm from the cathode.

4.4.5 Turn on the current and adjust to .3 amps. Electroplate for 1 hour.

4.4.6 Without cutting off the current, add 1 ml concentrated ammonium hydroxide and continue the electrolysis for 30 seconds.

4.4.7 Lift the anode from the cell and then switch off the current.

4.4.8 Disassemble the cell and remove the platinum disc.

4.4.9 Flame the disc to dull red over a Meker burner.

4.4.10 Mount the sample. Count the sample in an alpha spectrometer to resolve the isotopes of plutonium.

4.5 Processing of Plated Samples for Mass Spectrometry.

4.5.1 Place the platinum disc, plated surface up, in a clean 50 ml teflon beaker.

4.5.2 Cover the plated surface of the disc with 48% hydrofluoric acid (approximately 10 drops). Digest 30 minutes.

4.5.3 Place the teflon beaker on a hot plate, 320°C and evaporate the hydrofluoric acid to dryness. Do not bake.

4.5.4 Add 5 drops 48% hydrofluoric acid to the surface of the disc and evaporate.

4.5.5 Repeat 4.5.4 two times.

4.5.6 Add 5 drops 0.05M sulfuric acid to the surface of the disc and evaporate to the absence of SO_3 fumes.

4.5.7 Add 5 drops 48% hydrofluoric acid and evaporate.

4.5.8 Add 5 drops concentrated nitric acid and evaporate.

4.5.9 With stainless steel forceps, remove the disc from the beaker and holding the disc over the beaker, wash the surface of the disc dropwise with concentrated nitric acid into the teflon beaker.

4.5.10 Add 2 drops concentrated nitric acid to the plated surface and heat the disc gently over a low flame of a Meker burner. Wash the plated surface with a few drops of concentrated nitric acid into the beaker.

4.5.11 Repeat step 4.5.10 at least 9 more times.

4.5.12 Evaporate the accumulated washes to 0.5 ml. Transfer with distilled water to a 15 ml centrifuge cone. Keep the total volume about 5 ml.

4.5.13 Add 4 drops of lanthanum carrier. Mix thoroughly on a Vortex mixer and precipitate the lanthanum by addition of concentrated ammonium hydroxide. Add several drops excess.

4.5.14 Place the cone in a hot water bath to coagulate the $La(OH)_3$ precipitate. Centrifuge and discard the supernatant.

4.5.15 Wash the hydroxide precipitate with 6 ml water plus 2 drops concentrated ammonium hydroxide.

4.5.16 Dissolve the $La(OH)_3$ with 2 ml 1M nitric acid.

4.5.17 Add 2 ml of TTA*, mix thoroughly for 4 minutes. Centrifuge and transfer the TTA (top layer) to a clean 15 ml cone.

4.5.18 Repeat step 4.5.17 two times thus accumulating a total of 6 ml TTA in the cone.

4.5.19 Add 2 ml 1M nitric acid to the TTA and mix for 4 minutes. Centrifuge and transfer the TTA to a clean 15 ml cone.

4.5.20 To the TTA add 1 ml 10M nitric acid, mix for 3 minutes.

4.5.21 Repeat 4.5.20 two times.

4.5.22 To the 3 ml of 10M nitric acid add 2 ml TTA and mix for 3 minutes. Centrifuge and transfer the 10M nitric acid fraction to clean 15 ml cone.

*TTA is 0.2 N 4,4,4 Trifluoro-1 (2 thienyl) - 1,3 butane-dione in benzene.

4.5.23 Add 2 ml benzene to the 3 ml of 10M nitric acid. Mix for 3 minutes and centrifuge. Transfer the 10M nitric acid fraction to a clean 15 ml cone.

4.5.24 Place the cone in a hot water bath and evaporate to near dryness under a gentle stream of nitrogen. Add 4 drops of hydrochloric acid and evaporate to dryness. Add 4 drops of nitric acid and evaporate to dryness.

4.5.25 Remove the cone from the bath, add 1 drop 0.05M nitric acid mix. for 5 minutes. Centrifuge and load the one drop sample on a rhenium filament.

4.5.26 Measure the sample on the mass spectrometer.

APPENDIX I

DETAILS OF ALPHA SPECTROSCOPY

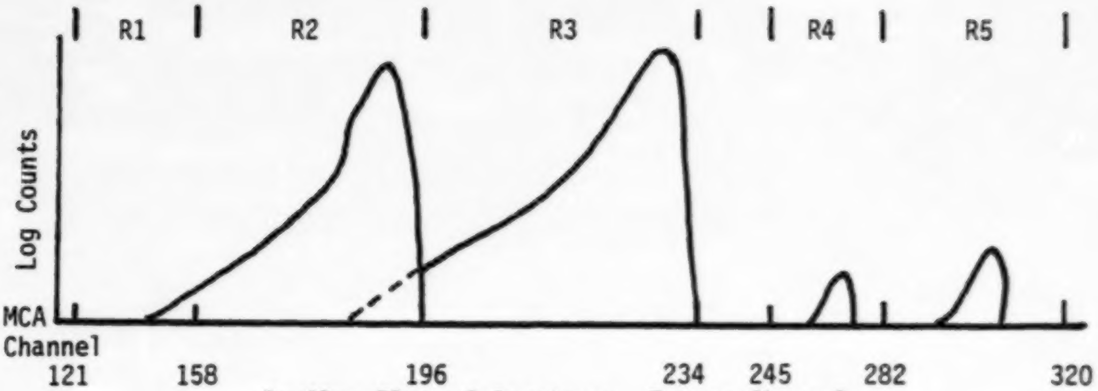
Samples are counted one time on either a Frisch Grid alpha detector or a silicon solid state detector. Both type of detectors are adequate for the study. The Frisch Grid spectrometers are capable of 50 KeV resolution of actual samples electrodeposited on flat, mirror-finished platinum planchets with a counting efficiency greater than 46% and a background less than 0.01 cpm over each designated energy region. The silicon solid state detectors are capable of 30 KeV resolution with a counting efficiency of 14% and a background less than 0.005 cpm.

(Resolution is defined as the full width half maximum in KeV, the distance between those points on either side of the alpha peak where the count is equal to one half the maximum count.)

The electrodeposition cell is a 1.8 x 7 cm plastic chimney that is set in a two piece stainless steel collar. The cathode is a 2.3 cm diameter, 0.004 cm thick platinum planchet that is held in place by the 2.3 cm teflon washer that seals the assembly. The anode is a 0.020 cm diameter platinum wire that is wrapped 6 times around a length of 2 mm I.D. pyrex tubing. Electroplating is conducted without stirring, using a 10-volt, 1 ampere power supply.

Figure I-1 illustrates a generalized alpha spectrum for plutonium.

APPENDIX I , CONTINUED



Semilog Plot of Counts vs. Energy Channel

Figure I-1. Generalized Alpha Pu Spectrum

Energy region R_1 contains the counts from the "tailing" of the Pu 242 tracer. The counts in the Pu 242 tail region is used to correct the Pu 242 peak for the tailing of the Pu 239+240. The tailing correction is calculated in the following manner. The Pu 242 and Pu 239+240 peak shapes are assumed to be the same. Therefore, the ratio of the counts of the Pu 242 tail region (R_1) to the counts of the Pu 242 in the Pu 242 peak region (R_2) is equal to the ratio of the counts of the Pu 239+240 tail in Pu 242 peak region to the counts of Pu 239+240 in the Pu 239+240 region (R_3) i.e.

$$\frac{\text{Pu 242 tail}}{\text{Pu 242 peak}} = \frac{\text{Pu 239+240 tail}}{\text{Pu 239+240 peak}} \text{...............Eq (1)}$$

Energy region R_2 contains the counts from the alpha decay of the Pu 242 tracer that is used to quantify the samples. Each sample is spiked with 3.45 ± 0.01 dpm of Pu 242. In addition to the Pu 242 peak, R_2 also contains counts that can be attributed to the Pu 239+240 tailing. The Pu 239+240 contributions to the total number of counts in R_2 is usually less than one percent.

Energy region R_3 contains the counts from the alpha decay of Pu 239+240. The samples are chemically purified and the tracer contains no measurable Pu 239+240 activity. Therefore, there are not extraneous alphas in this energy region.

Energy region R_4 contains the counts from Pu 238. The activity level of this isotope is usually below the limits of detection as determined by the sample size used for the study. However, the EPA does randomly spike tissue samples with Pu 236, Pu 238, and Pu 239+240 as a quality control measure. The fact that there is very little Pu 236 added means that, because of poor counting statistics, the peak shape is ill-defined, i.e. the presence and/or the shape of the tail is poorly defined. Since the ratio of the tail region to full peak area is small and the peak of Pu 236 is small compared to the area of Pu 238, tailing from Pu 236 into Pu 238 is negligible.

Energy region R_5 contains the counts from Pu 236.

CALCULATIONS USED IN DETERMINING ASSAY VALUES

The alpha particles from each of the plutonium isotopes is essentially monoenergetic. However, statistical variations of the counting system and an energy loss "tailing" towards the lower end of the spectrum give the spectral peaks the skewed, non-Gaussion shape illustrated by Figure I-1. Therefore, the plutonium spectral output must be analyzed by an energy range technique that compensates for tailing.

In order to use the energy range technique to resolve the data, the spectrum is divided into the five energy regions shown in Table I-1.

APPENDIX I, CONTINUED

TABLE I-1 PU ALPHA PARTICLE ENERGY REGIONS

Region	Isotope	Energy Mev	Channel
R_1	Pu 242 tail	4.424 - 4.683	121-158
R_2	Pu 242	4.690 - 4.949	159-196
R_3	Pu 239+240	4.956 - 5.215	197-234
R_4	Pu 238	5.292 - 5.551	245-282
R_5	Pu 236	5.558 - 5.824	283-320

CALCULATION OF DPM

The DPM value for each plutonium isotope is calculated in the following manner:

1. Divide the spectrum into its various components, R_1 - R_5, and sum the counts in each energy region.

2. Subtract background from each energy region, R_1 - R_5, of the spectrum. The background of each spectrometer is determined biweekly. Typical backgrounds are 0.004 cpm for each of the plutonium energy regions. A 5000 minute count is used to determine the background.

3. Determine the number of counts in R_2 that are attributable to Pu 239 and Pu 240 tailing. This is done by solving the ratios equality, Eq. 1, for counts in the Pu 239 and Pu 240 tail.

$$\text{Pu 239 and Pu 240 tail} = \tfrac{1}{2}\{R_2 + \sqrt{(R_2)^2 - (4 * R_1 * R_3)}\}\text{ ....Eq (2)}$$

where:

R_2 = total counts in the Pu 242 peak region R_2

R_1 = total counts in the Pu 242 tail region

R_3 = total counts in the Pu 239 and Pu 240 peak region

4. Determine the number of counts in R_2 that are attributed to the Pu 242 tracer.

Pu 242 (corrected count rate) = Total counts R_2 - counts in R_2 from Pu 239 and Pu 240 tail..Eq (3)

5. Calculate the DPM of Pu 236, Pu 238, and Pu 239 and Pu 240 in the sample at (t_m) time of measurement. Where DPM (Pu) m = DPM of Pu at time of measurement.

$$\text{DPM (Pu 236)}_m = \frac{\text{(Pu 236 counts) * (DPM Pu 242 tracer)}}{\text{Pu 242 counts}}$$

$$\text{DPM (Pu 238)}_m = \frac{\text{(Pu 238 counts) * (DPM Pu 242 tracer)}}{\text{Pu 242 counts}}$$

$$\text{DPM (Pu 239+240)}_m = \frac{\text{(Pu 239+240 counts) * (DPM Pu 242 tracer)}}{\text{Pu 242 counts}}$$

6. Decay correct the DPM values for Pu 236 and Pu 238 to 1 January of the year of measurement (t_o). Where DPM $(\text{Pu})_o$ = DPM at 1 January.

$$\text{DPM (Pu 236)}t_o = \text{DPM (Pu 236)}_m * e^{\lambda(\text{Pu 236}) * (t_m - t_o)}$$

$$\text{DPM (Pu 238)}t_o = \text{DPM (Pu 238)}_m * e^{\lambda(\text{Pu 238}) * (t_m - t_o)}$$

7. The half life of Pu 239 and Pu 240 are long. Therefore, no decay correction is applied to the Pu 239 and Pu 240 values.

8. See discussion of the statistical analysis of alpha spectroscopy data in the main text, under Section 2, "Determination of Pu, Laboratory Analysis." The criteria for determining when an alpha count is significantly different from background is described there. (Pages 61-63.)

APPENDIX J

DETAILS OF MASS SPECTROMETRY

The mass spectrometer is a three stage, surface ionization instrument that is operated in the pulse counting mode. The first two stages consist of 12 inch, 90° magnets that are placed in the "C" configuration. The third stage is a 60°, 14.4 inch radius doubly focusing electrostatic lens. Canoe filaments made of zone refined rhenium are used to ionize the sample.

Figure J-1 illustrates a typical mass spectrum collected by this technique.

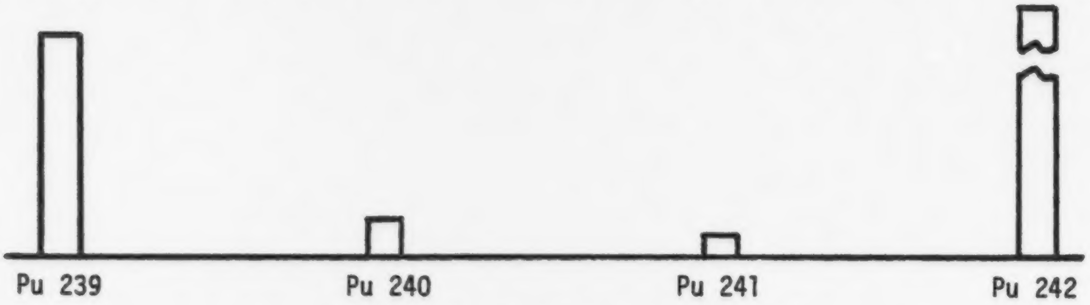


Figure J-1. Typical Mass Spectrum

The spectrometer is programmed to alternately sweep up and back down through the mass region from 238.5 to 242.5. Measurements are taken at 238.5, 239, 239.5, 240, 240.5, 241, 241.5, 242 and 242.5 masses. One measurement is made at each mass position as the spectrometer sweeps up the mass region; a second measurement is made as the spectrometer sweeps back down the mass region. The cycle is repeated ten times and the number of counts at each mass that were accumulated during the ten sweeps is summed to form a data acquisition set. Table J-1 shows the counting times at each mass position.

APPENDIX J, CONTINUED

TABLE J-1.COUNTING TIMES

MASS	COUNT TIME (SWEEP)	COUNT TIME (ACCUMULATED)
238.5	0.100 sec	1.000 sec
239	3.000	30.000
239.5	0.100	1.000
240	3.000	30.000
240.5	0.100	1.000
241	3.000	30.000
241.5	0.100	1.000
242	0.300	3.000
242.5	0.100	1.000

Several data acquisition sets are taken per sample. The number of sets vary from sample to sample. A typical sample produces four to eight data sets.

The mass spectrometry data is reported as atom ratios and as dpm Pu 239+240. The equations used to develop those numbers and associated error terms are described as follows:

Calculations Used in Determining the Atom Ratios for a Single Data Acquisition Set

1. Determine the count rate in counts/sec. for all peaks and background in the data acquisition set.

$CR(m) = \text{counts } (m)/T$

$CR(m) = \text{counts collected at mass } (m)=\{238.5, 239, 239.5, 240, 240.5, 241, 241.5, 242 \text{ and } 242.5\} \div T$

$T = \text{time in secs.}$

APPENDIX J, CONTINUED

2. Correct count rate at each mass for dead time.

$$CR_{\tau}(m) = \frac{CR(m)}{1 - CR(m)\tau}$$

$CR_{\tau}(m)$ = dead time corrected count rate for mass m

τ = dead time of system i.e., $3.5 \times 10^{-8} \pm 10\%$ sec

3. Form atom ratios that have been corrected for background. Pu 239 is used as the reference isotope.

$$R(i/{}^{239}Pu) = \frac{CR_{\tau}(i) - 0.5\left[CR_{\tau}(i + \tfrac{1}{2}) + CR_{\tau}(i - \tfrac{1}{2})\right]}{CR_{\tau}{}^{239}Pu - 0.5\left[CR_{\tau}(239.5) + CR_{\tau}(238.5)\right]}$$

i = ${}^{240}Pu$, ${}^{241}Pu$, ${}^{242}Pu$

$i \pm \frac{1}{2}$ = half mass backgrounds associated with specific plutonium isotope.

239.5 and 238.5 = background half mass positions associated with reference isotope ${}^{239}Pu$.

4. Correct all ratios for mass bias.

$$R_T(i/{}^{239}Pu) = R(i/{}^{239}Pu) \cdot MB$$

R_T = atom ratio corrected for mass bias, background and deadtime.

MB = mass bias factor

MB = $1-k(M_n-M_d)$ where M_n = mass numerator

M_d = mass denominator

$k = -0.0035 \pm 10\%$

Formation of the Average Atom Ratio

1. Form the simple average of the data acquisition sets.

$$\bar{R}(i/{}^{239}Pu) = \frac{\sum_{J=1}^{n} R_{T_J}(i/{}^{239}Pu)}{n}$$

n = number of data acquisition sets

$\bar{R}(i/{}^{239}Pu)$ = simple average atom ratio

Formation of Percent Deviation Associated with Simple Average Atom Ratio

1. Calculate standard deviation associated with $\bar{R}(i/{}^{239}Pu)$

$$\sigma^2(i/{}^{239}Pu) = \frac{\sum_{J=1}^{n} \left(R_{T_J}(i/{}^{239}Pu) - \bar{R}(i/{}^{239}Pu)\right)^2}{n-1} \equiv \qquad \text{Ref Eq. I}$$

$$\frac{n \sum_{J=1}^{n} R_{T_J}(i/{}^{239}Pu)^2 - \left(\sum R_{T_J}(i/{}^{239}Pu)\right)^2}{n(n-1)}$$

$\sigma\,(i/{}^{239}Pu)$ = standard deviation

2. Calculate standard error associated with $\bar{R}(i/{}^{239}Pu)$

$$\sigma_{\bar{R}}^{\,2} = \frac{\sigma^2(i/{}^{239}Pu)}{n}$$

$\sigma_{\bar{R}}$ = standard error

3. Calculate percent deviation associated with $\bar{R}(i/{}^{239}Pu)$. This calculation uses standard propogation of error techniques to include errors from $\sigma_{\bar{R}}{}^2$ and uncertainty in dead time and mass bias.

The generalized equation has the form:

$$\sigma(x) \doteq dx = \left[\sum_{k}^{n} (dx/dn_k)^2 (\Delta n_k)^2\right]^{\frac{1}{2}} \qquad \text{Ref Eq. II}$$

where k = the number of independent variables

This method assumes that all variables are uncorrelated and that the uncertainties on each variable, Δ nj are small. The specific equation used is:

$$\text{PCT DEV} = \frac{1}{\bar{R}}\left[\sigma_{\bar{R}}^{2} + \left(\frac{\bar{R}}{MB}\right)^2 * \sigma_{MB}^2 + \left(\left(\frac{\left(\frac{\bar{R}}{MB} - 1\right)}{1-F*\tau}\right) *F\right)^2 * \sigma_{\tau}^{2}\right]^{\frac{1}{2}} * 100\%$$

where

$$F = \frac{\sum_{j=1}^{n} CR_{\tau}(m) * T(m)_i}{\sum_{j=1}^{n} T(m)_i}$$

For the sample size and count rate used for these analyses, the errors associated with the mass bias and dead time make negligible contributions to the percent deviation. Therefore the percent deviation reduces to:

$$\text{PCT DEV} = \frac{\sigma_{\bar{R}}}{\bar{R}} * 100\%$$

Reject Ratios Via Chauvenet Criterion

The set of atom ratios are checked for outliers by use of the Chauvenet rejection criterion.

APPENDIX J, CONTINUED

1. Compare $\sigma(i/^{239}Pu)$ (Eq.I) with the maximum deviation,

$$\left[R_{T_J}(i/^{239}Pu) - \bar{R}(i/^{239}Pu) \right]_{max}$$

2. Depending upon the number of ratios "n" and the Chauvenet table, decide whether or not to reject the ratio (e.g., N-10; reject if

$$\left[R_{T_J}(i/^{239}Pu) - \bar{R}(i/^{239}Pu) \right] max > 1.96\, \sigma (i/^{239}Pu)$$

3. If a point is rejected, recompute $\bar{R}(i/^{239}Pu)$, $\sigma(i/^{239}Pu)$, and $\sigma_{\bar{R}}$ and apply the criterion again with (n-1) points.

This completes calculation of the observed atom ratio and the associated percent deviation.

Calculation of DPM Values and Associated Errors for Mass Spectrometry Data

1. Calculate number of atoms in sample.

$$\text{Atoms } X = \frac{A}{B}$$

X = atoms of ^{239}Pu

A = atoms ^{242}Pu tracer added

B = ^{242}Pu/^{239}Pu isotope ratio measured in sample

Atoms Y = (Atoms X)$\cdot$ C

C = Ratio of ^{240}Pu, to ^{239}Pu in sample

This assumes that there is no ^{242}Pu present in the samples.

2. Calculate error associated with number of atoms in sample.

   Equation II is used to propogate error associated with uncertainty in atoms of ^{242}Pu added and uncertainty in measurement of atom ratio of sample.

3. Calculate $^{239+2340}$Pu dpm value for sample

$$\text{dpm}\ ^{239+240}\text{Pu} = \text{atoms}\ ^{239}\text{Pu}\ \lambda_{^{239}\text{Pu}} + \text{atoms}\ ^{240}\text{Pu}\ \lambda_{^{240}\text{Pu}}$$

4. Calculate percent standard deviation associated with dpm $^{239+240}$Pu

$$\%\sigma\ \text{dpm}\ ^{239+240}\text{Pu} = (100\%/\text{dpm}\ ^{239+240}\text{Pu}) \cdot \left[\lambda^2_{^{239}\text{Pu}} \cdot \sigma^2_{^{239}\text{Pu}} + \lambda^2_{^{240}\text{Pu}} \cdot \sigma^2_{^{240}\text{Pu}}\right]^{\frac{1}{2}}$$

$$\lambda_{^{239}\text{Pu}} = 5.405 \times 10^{-11}$$

$$\lambda_{^{240}\text{Pu}} = 2.008 \times 10^{-10}$$

This completes the calculations used to determine the $^{239+240}$Pu values in a sample.